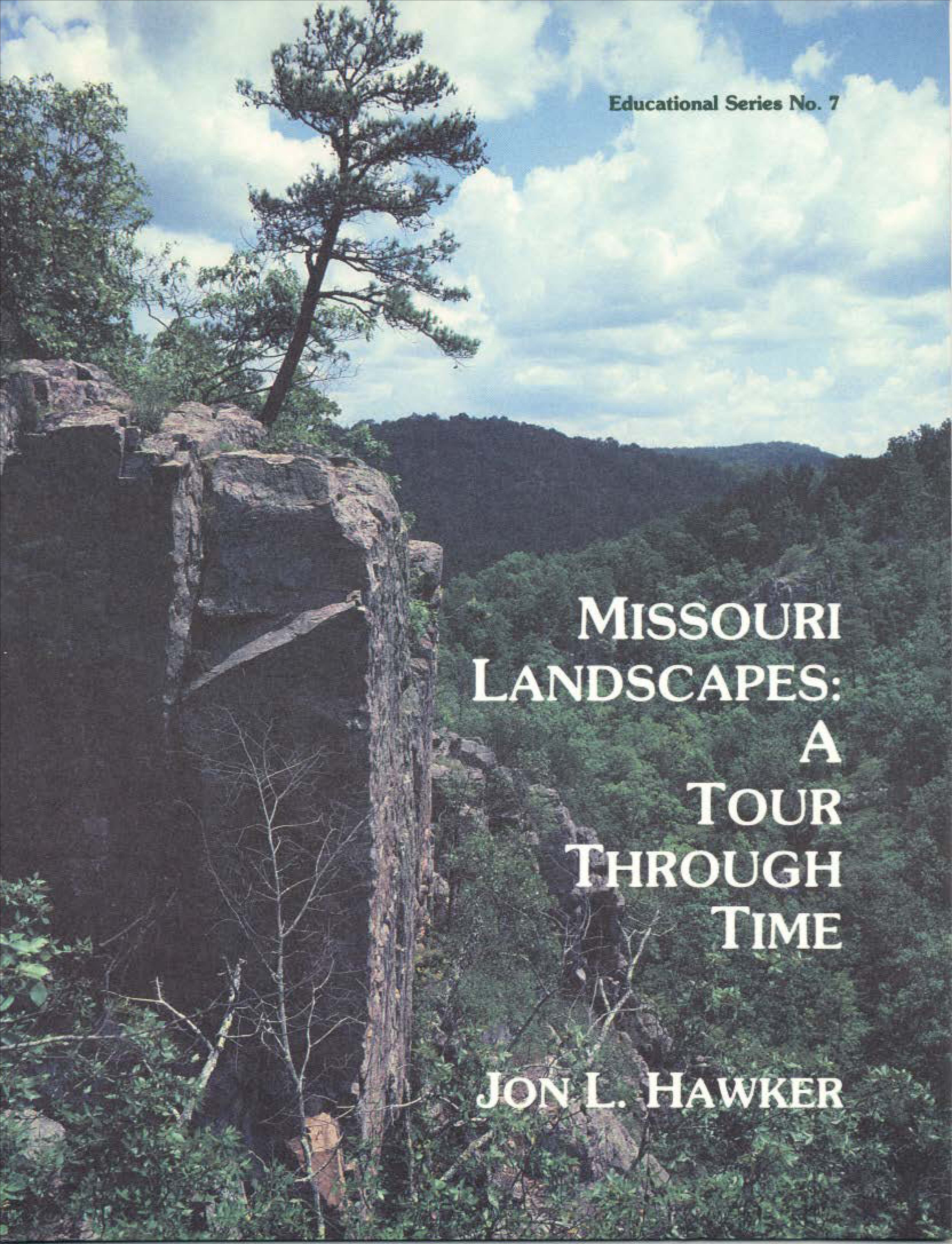

Educational Series No. 7

MISSOURI LANDSCAPES: A TOUR THROUGH TIME

JON L. HAWKER

This book is dedicated to my parents,
who for 35 years encouraged me in my pursuit of natural history,
even though they had never heard of a rich natural historian.
They put up with snakes and toads in the basement,
turtles in the backyard, weeds in the garden,
bugs in the refrigerator,
and mud everywhere...

Front Cover: *Volcanic igneous rocks more than a billion years old lie exposed in cliffs along Prairie Hollow Canyon near Eminence, in a landscape typical of the rugged Missouri Ozarks. The mixed forest of hardwoods and pine is the result of biological development that began from the earliest stirrings of life and became not only part of the landscape, but also a powerful agent of change. Photo by Jon L. Hawker.*

Back Cover: *The urban landscape is home to more Missourians than any other, yet it is frequently thought of as a place to escape from rather than come home to. Nevertheless, cityscapes with buildings and power lines reflect the disappearance of much of the treasured natural landscape that once was the face of Missouri. Photo by Nick Decker*

Educational Series No. 7

Missouri Landscapes: A Tour Through Time

by
Jon L. Hawker
St. Louis Community College

Missouri Department of Natural Resources
Division of Geology and Land Survey
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NOTICE: The Department of Natural Resources presents this book as a substantial contribution to the understanding of the origin and development of the landscapes of Missouri. The opinions of the author, Jon Hawker, and his interpretations of the geological and biological history of Missouri are entirely his own, and do not necessarily reflect the philosophy and management practices of the Department.

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Foreword

Heraclitus' saying that "All is flux, nothing stays still," is an apt summary of this book. Jon Hawker, whose credentials qualify him to write of both geology and biology, begins his "tour through time" as far back as physical science will allow the mind to explore. He discerns the first stirrings of life on Earth, and traces the waxing and waning of plant and animal species through the eons of geological history.

The varied landscapes of Missouri emerge in word-pictures as timeless vistas of geological and biological change, not necessarily as improvements, but as products of infinitely complex environments. From a history of cataclysmic volcanic activity through successive and incredibly long periods of erosion, submergence beneath ancient oceans, sedimentation and uplift, and great continental glaciers, the landscape of the rugged Ozarks, the wide, flat Bootheel, and the rolling hills of north Missouri seem reasoned and somehow appropriate.

-- **G. Tracy Mehan, III**
Director,
Missouri Department of
Natural Resources
January 1989 to July 1992

Life itself is seen as ever-changing, and a powerful agent of change. The fossilized bodies of crinoids--once an amazingly prolific marine animal--now form one of Missouri's most familiar and useful rock formations: the Burlington Limestone. Dinosaurs once roamed what is now Missouri, and primitive, tree-like plants formed the first forests. Soil would not be possible without microscopic organisms that interact with mineral particles to form a growth medium for higher forms of life.

Missouri landscapes changed imperceptibly slowly until the arrival of a new species, Homo sapiens--Man--who accelerated and forever altered the face of Missouri. Until Man, no form of life produced energy not of its own life force; no other species used artificial light; none required other than rudimentary shelter. No other species ever buried its dead; none required music and art; none ever developed artificial locomotion. In all of Earth history, no species acquired the power to leave the Earth, until 20th century space travel.

Viewed against the backdrop of geological time, the face of Missouri has been altered in an eyeblink, since native peoples and then European settlers arrived on the scene. The land survey system, completed in the early 1800s, imposed a checkerboard pattern that controls agricultural lands and urban development, as well as transportation networks. Technology enabled humans to raise tall buildings, bridge rivers, build dams to form lakes, and to burrow far beneath the land to recover mineral resources. Trains and trucks, boats and planes, and the automobile give mobility unknown and unimagined just a few generations ago. Electronic communications and satellites in space place Man on the threshold of global governance.

The human species has dominated the Missouri landscape as no other species--not even the mighty dinosaurs--has ever done. Exploding from small numbers to more than five billion individuals in just a few thousand years, technology has made possible enormous changes that have come so rapidly there has not always been enough time to consider the consequences.

We have arrived at this way station in time willy-nilly, driven by necessity, convenience or, at times, perhaps, greed. However, the enormous powers harnessed by human ingenuity offer an unparalleled opportunity to build a better future, to erase the mistakes of the past, to restore lost landscapes, to avoid the fate of countless species that held sway for a time, then passed into extinction.

For countless ages, life forms were a product of their environments; for the coming age, for good or ill, the environment will be a product of the highest of all life forms--human beings.

G. Tracy Mehan III

Introduction

The Missouri Landscape

Straddling the broad spine of one of the massive pink elephants in Elephant Rocks State Park, scanning the horizon, we may be struck not by the rugged, mountainous nature of the Ozarks, but by their flatness. At our feet, the sun glints back from durable crystals that have gleamed for millions of years from between crusty patches of gray-green lichen. Initials carved into the rock identify a few of the people who began to cut and polish slabs of these boulders for buildings and monuments over a century ago. The leaves on the stunted trees are a delicate green, having emerged only recently, but it is a wildflower, a clump of intensely scarlet fire pink that catches our eye.

Later, not far away, having crossed streams choked with orange gravel and lined by gray cliffs, we cool our feet in a spring branch and wonder about shapes in a pebble that resemble some kind of plant or animal, we're not sure which, but which we know are unlike anything we've seen living today. A school of laughing canoeists drifting downstream backwards offers us a beer.

Driving home, sometimes a twisting, roller coaster ride on roads without shoulders, we pass patches of shriveled corn no higher than a grasshopper's thigh and weedy fields with a few cows, or maybe a horse or two. Along the way the woods are mostly short and scrubby, and not at all reminiscent of forest. The rest of the trip home is a race on the interstate, and a week later we share our snapshots with friends, or watch the video we made.

On another trip, this time to the southeastern part of the state, we drive for miles through forests of corn, meticulously levelled rice paddies, and endless rows of soybeans and cotton, without topping a single hill. We cross dozens of "creeks," simple strips of still water bordered by low levees that disappear unswerving into the green fields. The trees in the farmyards and small towns are statuesque, the way we imagine they would be in a real forest. Yet there doesn't seem to be much real forest in this part of the state. The tallest things are grain elevators and power lines, planted in the dark soil like monuments. Passengers doze and read, waiting for a stretch of road with more interesting scenery.

On another highway later in the year, the scent of mown and drying hay fills the car, blessed relief for a portion of our brain overwhelmed by hogs a few miles before. The drive is largely a pleasant one, through rolling, open terrain dotted with hundreds of red barns and white farm houses. Along the streams, elms and hickories have turned yellow, and an occasional sugar maple is strikingly orange. Roadside stands sell cider, a dozen kinds of apples, and enormous pumpkins. Herds of swollen and impatient Holsteins on their way to the milking barn remind us of T-shirts and ice cream from Vermont. In contrast, the drying shed of a tobacco cooperative brings North Carolina and the Old South to mind.

What do these images have in common?

They represent various aspects of the Missouri landscape, a unique blend created by geologic, climatic, biologic, and human influences. We are about to undertake a tour of that landscape, in time as well as in space.

We begin with a description of Missouri's natural communities and the factors that determine which kinds of plants and animals will be found in various parts of the state. We then explore the geologic and evolutionary orgins of the Missouri landscape, back to the beginnings of the earth itself. Finally, we trace the changes in that landscape imposed by humans, arguably the single most influential species on the planet.

Acknowledgments

Thoughts about a book about Missouri natural history first took shape in my tiny little brain more than 20 years ago, when I began teaching a field biology course at Meramec Community College. Because there was no single account for the average person that explained the geologic, prehistoric, and historic influences which have created the modern Missouri landscape, I decided to assemble one. From this first version - a mere 20 pages in length - the project progressed through a number of metamorphoses, expanding at each step like some sort of deviant fungus. A portion of the resulting mass now emerges as this book; there is enough remaining for three others of comparable length on Missouri's aquatic systems, forests, and grasslands. Those may yet appear in print. This one would never have appeared in its current manifestation were it not for the help of many people.

I wish to thank my colleagues and the administration at St. Louis Community College at Meramec, and the Board of Trustees of the Junior College District of St. Louis - St. Louis County, who saw the value in publishing this information and who granted released time and a sabbatical in which to carry on the research and writing. Media and photographic support were provided by the college through the efforts of Larry Kuban, Nancy Randazzo, and Paul Talaski. Candy Finkelston and the entire library staff at the Meramec campus provided years of priceless service tracking down obscure references and odd bits of information. Moral support came from many firends and family, especially Mary Hawker, who did much research and editing early on, and Patricia Hawker, who "volunteered" to review parts of the manuscript and who corralled countless stubborn subjects for photographs.

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Douglas Givens of St. Louis Community College at Meramec; their sound advice is gratefully acknowledged. Their corrections, suggestions, and ideas are woven into the text; any errors that remain are entirely my own. Fred Gaarde of Triad Research Services kindly allowed me to photograph progress at an archaeological dig in St. Charles County.

Betty Harris of the Department of Natural Resources patiently edited the text, making certain that I dotted all my i's and crossed all my t's. The text was then painstakingly formatted and laid out by Susan Dunn, also of DNR; her efforts resulted in a presentation of which any author would be proud. Over the years, hundreds of my students have served as guinea pigs and have offered suggestions for clarifying explanations and making the text accessible to the average reader. If the language remains technical or unclear in places, it's not that we haven't tried.

Finally, I give especially warm thanks to Jerry Vineyard, who not only read the entire manuscript for readibility and accuracy, but whose initial interest, prodding, poking, and determination made certain that the book actually got into print.

Missouri - A Biological Melting Pot

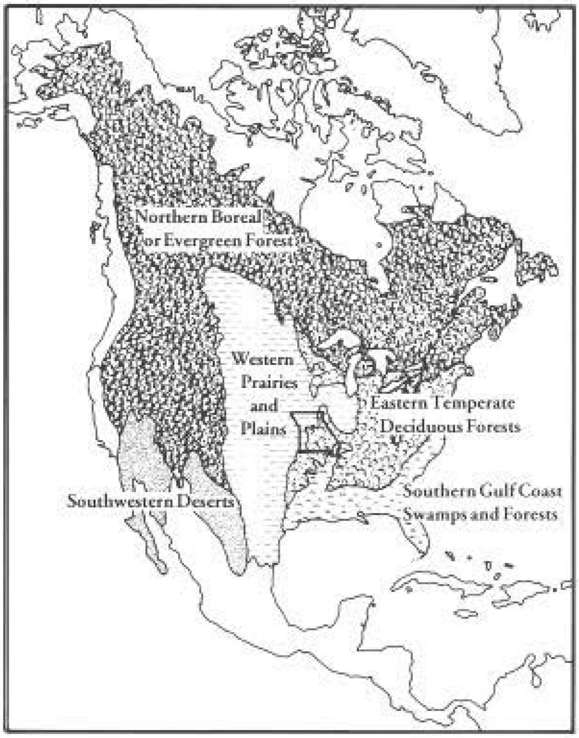
Nearly every region in the United States has its own characteristic assemblage of plants and animals that immediately distinguishes it from all others - southwestern desert, central grassland, eastern forest, and so on. Any broad geographical area dominated throughout by a similar set of climatic conditions and natural history (regardless of whether it crosses state lines or not) is referred to by ecologists as a **biome**. Biomes - such as desert, grassland, or deciduous forest - are simply convenient labels for the largest natural communities generally recognized by ecologists.

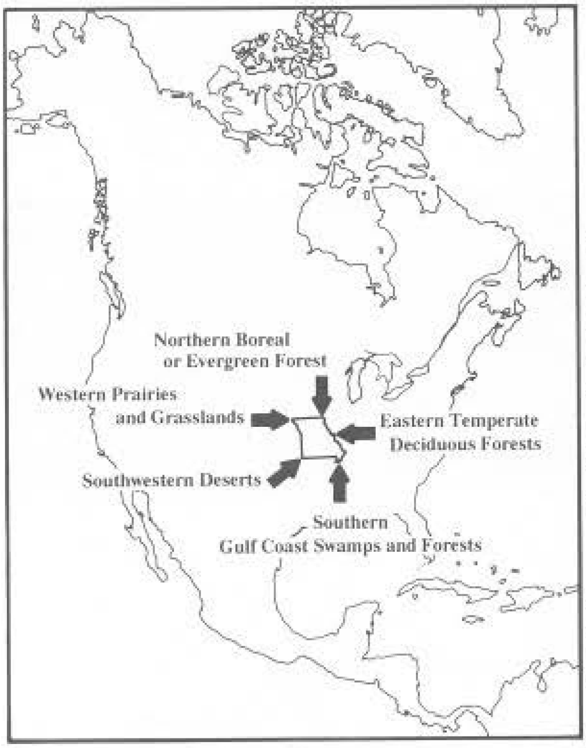
Biomes are also easily recognized by we non-ecologists, even without years of experience and technical training. To most people, desert, whether in Arizona, South America, Asia, or Africa, pretty much looks like desert. Grasslands in the steppes of central Asia or the pampas of Argentina differ little in their general appearance from the prairie of Oklahoma, Kansas, or Nebraska. The woods, whether here or in Britain, France, or Japan, are clearly recognizable to all as forest.

While lying in the heart of the nation, Missouri is not in the heart of any one biome and expresses none of them perfectly. Instead, Missouri offers its own Midwestern impression of each of several biomes. It is here that five distinctive biomes meet, overlap, and become lost in the others.

Although biomes are most easily represented by lines on a map, their boundaries on the ground are not quite that sharp or distinct. We cannot walk across North America following a little black line that separates forest from prairie, trees on the right, grass on the left, as if they had been neatly laid out by some cosmic landscape architect. Biomes are not so easily delineated.

The principal biomes of North America relevant to Missouri natural history.


Northern Boreal or Evergreen Forest
Western Prairies and Plains
Eastern Temperate Deciduous Forests
Southwestern Deserts
Southern Gulf Coast Swamps and Forests


Northern Boreal or Evergreen Forest
Western Prairies and Grasslands
Eastern Temperate Deciduous Forests
Southwestern Deserts
Southern Gulf Coast Swamps and Forests

Missouri receives plants and animals from five principal biological regions of North America.

America's western grasslands, the shortgrass plains and tallgrass prairie, are swallowed almost imperceptibly by her eastern temperate deciduous forests, the familiar woods of oak, hickory, and other trees that drop their leaves in winter. Most of Missouri's familiar wildflowers and animals are representative of this eastern forest. Prairie species include buffalo (or American bison), blue grama and hairy grama grass, purple beardtongue, bur oak, plains killifish, prairie skink (a lizard), greater prairie chicken, and the thirteen-lined ground squirrel.

Similarly, along a north-south gradient perpendicular to the first, the vast northern Canadian boreal forest, dominated by evergreen conifers such as spruce and fir, and the swampy southern Gulf Coast forest of bald cypress gradually fade into one another within the borders of Missouri. From the north, Missouri has received an influx of species such as quaking aspen, common chokecherry, northern pike, burbot (a freshwater cod), wood frog, snow bunting, and least weasel. From the south have come bald cypress, corkwood, green tree frog, alligator snapping turtle, cottonmouth, snowy egret, and swamp rabbit.

From the Gulf Coast Missouri has received swamps of bald cypress and tupelo gum.

Jon Hawker

Fingers of southwestern desert creep east and north into the mix and gradually disappear on barren Ozark hillsides called glades. In such dry, rocky places may live the prickly pear cactus, western soapberry, poison oak, tarantula, scorpion, collared lizard, coachwhip snake, and roadrunner.

Missouri presents an unmappable brew of these five biomes. Such an indistinct zone of blending between two or more biomes, or between any two smaller biological communities for that matter (woods and fields, for instance), is known as an **ecotone**. The overlapping creates a boundary zone of unusually high species diversity, that is, an area with a large number of different kinds of organisms.

Jon Hawker

One of Missouri's best grasslands can be seen at Prairie State Park near Liberal, Missouri in Barton County.

An ecotone represents a region where living conditions are less than optimal for the full development of either of its bordering biomes. Each biome is well-developed at the center of its range where conditions are optimal, such as the saguaro cactus desert in Arizona, the windswept grassland of South Dakota, or the dense forest of the Great Smoky Mountains. But the characteristic species of each biome decline in number near the edges of its range. At some point the environment becomes so ill-suited that none of the species typical of the biome are able to survive.

In the meantime, however, plants and animals representative of the neighboring biome gain both in numbers and in kinds. However marginal, the conditions in the ecotone between two biomes are usually sufficient for the survival of a fair number of species from each.

While an ecotone cannot boast the full complement of species from any of its neighboring communities, it will commonly have enough from each to ensure that its total number is actually greater than that found in either one of the biomes by itself; thus, the pure grassland of the Dakotas generally has only those species that are native to the grassland, with few or no forest species at all. Similarly, the richest eastern temperate deciduous forests, the Gulf Coast bayous, and the southwestern deserts have their own characteristic mixes of species, but few or none of those typical of their neighboring biomes.

An ecotonal area, such as Missouri, will have many plants and animals that characterize its neighboring biomes and will therefore have a unique blend that none of those areas can display on its own. If one compares the general appearance of Iowa with Arkansas, or contrasts Nebraska with Tennessee, or Kansas with Illinois, one can see how Missouri serves as a zone of blending between areas that are completely different in character.

Because Missouri is essentially a giant ecotone between the biomes of north, south, east, west, and southwest, the total number of species found within its boundaries is far greater than might be expected if Missouri were occupied by a single biome.

Where Are We Going?

"Where are we going?" is certainly one of the most frequently asked questions in the English language, especially if the askee is a parent or a field trip leader. It would surely be a logical question to ask before setting out on any tour of Missouri, especially a tour through time. There are actually a number of different answers imbedded in this "Where?" inquiry. In response, we might say that we will be in Lincoln or Grundy county, or some other political entity. We could give a nearby town or landmark as our destination, such as "We're

Susan Dunn

White Oak Pond, off Highway 5 south of Lebanon, began as a sinkhole, and became a natural pond when the bottom drain in the sinkhole became clogged with mud.

going to New Madrid," or "We'll be in Mark Twain National Forest." We might even offer a very precise destination, such as Grindstone Hill, Red Sink, or Elk Lick Springs. Still, few of the askees would have any better idea where they were going and, once returned, perhaps not a clue as to where they had been. We could draw a map, give the route and mileage, include the compass bearings and distance, and maybe the exact grid coordinates.

Unfortunately, even if we have all this information, we may still have no better idea of where we will actually be. We will still be unable to visualize where this place really is, what the place is like, biologically-speaking; what lives there and what we will shall see. In fact, coordinates, distances, and directions may only confuse us or give a false impression. Counties and national forests are awfully big places and encompass many different kinds of environments. Is it wilderness or near a city or town? Will it be wet? Will we need hiking boots? What's there? If we haven't been there, names, maps, directions, and such just won't mean a thing. To create a mental image of where we are going, some sort of description of its natural environment must be included. Once we have a vague picture of the geology and vegetation - is it glade, prairie, or forest, for instance - we can pretty accurately conjure up an impression of the place, even without ever having been there. Provided, of course, we have some idea of what glades, prairies, and forests look like.

Simple descriptive phrases can cue us to the geology and vegetation of a place. "Oh, you'll like it. It's got a great trout stream," or "It's the neatest place. We were there last year, climbed all day, hiked for hours through the woods, and never saw a soul. We were really beat when we got home. I tore my pants." We already know that the stream will be swift, clear and cold, likely rocky with a fair amount of aquatic vegetation, and 650 fishermen standing cheek to jowl. The second site obviously offers rocky hillsides or bluffs, probably covered by second growth oak and hickory forest, tangled, a bit rugged, and begging repellant.

Using phrases just a bit more precise can accurately describe the site. More precise phrases are an absolute necessity for biologists, because the woods are not all the same. Neither are prairies and streams. We expect to find one set of plants and animals in a forest, a different set in a prairie, a third in a stream. We also expect two different streams or two different prairies or two different patches of woods to have roughly the same kinds of creatures. It is logical that the same sets of conditions will attract the same sorts of species. Biologists recognize the logic. They refer to each of these groups of organisms living together under a preferred set of conditions as a **natural community**. They also recognize that natural communities may be of any size. Among the largest communities they label are the biomes, some of which may cover half a continent.

Jon Hawker

A cluster of goldenrod flowers is a complete community, including small plant-eaters, predatory spiders, and these pollen-eating blister beetles.

When we take a closer look, we see that a biome is not uniform throughout. Each biome consists of a number of smaller communities, each with its own local mix of plants and animals. The eastern temperate deciduous forest biome in Missouri is woods everywhere, but it may be dominated by white oak and sugar maple on deep, rich, upland soils; by shortleaf pine and black oak on rocky, acid soils; and by post oak and shagbark hickory on shallow limestone soils. Valley floors and ridge tops, flood plains and rolling hills, while wooded, each support different types of forest. Each of the distinct communities within the forest biome develops under its own preferred, slightly different set of local environmental conditions. Many wildflowers, insects, birds, and mammals are dealt among the smaller communities in a similarly selective fashion. Prairies and other biomes may be subdivided in like manner.

The division of the earth's living landscape into natural communities does not end with the large biomes and their major subcommunities. Even smaller communities exist within the local divisions of forest, prairie, and stream. A sampling of some of these smallest Missouri natural communities might include a rotten log, a drying pile of buffalo dung, a cluster of goldenrod flowers, or a tiny drop of dew on a daisy petal. Depending on how fine the distinctions are made, Missouri may be home to hundreds or even thousands of distinct natural communities. Each supports its own unique group of organisms adapted to the special conditions offered within that community. Such tiny communities exist because something, some structure, has altered living conditions and offers a site that differs from the nearby surroundings. Ecologists call such altered conditions a **microclimate**, literally a small climate, and refer to the altered place where a group of plants and animals can live as a habitat or, if small enough, a **microhabitat**. A very small microclimate can thus provide a microhabitat, a tiny place to live.

The natural world is generally occupied by groups of plants and animals, called communities, that live together under similar sets of environmental conditions.

Tiny Places To Live

Because plants typically dominate the environment in number and size, it is logical that they also dominate their surroundings physically. In order to successfully compete with nearby vegetation, most plants have a natural tendency to climb or spread over the land and their neighbors if possible. The greater the competition for light, the higher the plants will grow, within certain limits. Whether in forest or grassland, the dominant vegetation, the highest or tallest plant group, is exposed to the full impact of sun, wind, and rain. Their efficient, light-gathering leaves must not only absorb as much sunlight as possible, they must also be resistant to both wind and rain. Drooping, resilient, and hung on flexible stems, the leaves of these dominants are among the most important structures in the community. The mere presence of structures of any kind, including plants, rocks, or logs, blunts the impact of several powerful environmental forces.

The upper layer of trees produces a more or less complete covering of leaves, twigs, and branches called a **canopy**. The canopy receives the direct rays of sunlight, absorbs much of the solar onslaught, and provides shade. Some of the incoming sunlight is reflected directly back to space as light. Through photosynthesis, some is captured as chemical energy in the form of sugar. The rest is converted to heat and is also radiated back to space. As a result of their exposure to direct and continuous sunlight, canopy leaves are usually tougher than leaves on lower branches. They have to be. The canopy is the harshest place to live in a forest.

With the reduction in solar input produced by its shielding leaves, air temperatures under the forest canopy will be measurably lower on a hot summer day. This is, of course, the main reason people plant shade trees. At the same time, wind speed in the forest is greatly reduced. Upon entering the forest from a hot, sunny field, we immediately notice the cooler temperature. But we also note the lack of any refreshing breeze. Overhead, the rustling in the canopy reveals where the breeze has gone. All the energy has been absorbed by the leaves and stems of the dominant vegetation. The movement of air overhead is translated into rippling and swaying; beneath the canopy, the air is still. And that is why farmers plant windbreaks. 'Way overhead, out of sight, baked by the sun and thrashed by the wind, the canopy leaves lose tremendous amounts of moisture every day. They would lose even more if they had a large surface area. Consequently, canopy leaves are not only tougher than leaves lower down on the same tree, they are usually smaller as well.

The canopy absorbs the brunt of the sun and weather. Champion bur oak, Big Oak Tree State Park, Mississippi County.

Jon Hawker

The wind passing across the tops of the trees moves relatively fast compared to the air beneath the canopy. By constantly carrying off the water lost by the leaves during **transpiration** (the process of water loss from plants similar to perspiration in humans), the wind maintains a fairly low relative humidity above the trees. However, because the air under the canopy moves slowly, it picks up far more water in its tedious journey through the forest. The relative humidity under the canopy often approaches 100 percent of saturation, even though the air outside the forest may con-

Jon Hawker

Delicate ferns thrive in the cool shade. Hickory Canyons, Hawn State Park, Ste. Genevieve County.

tain only half as much moisture. With high humidities and no wind, our slightest exertion in the summer forest is answered by rivulets of sweat. Deceived by the forest's dense shade and somewhat cooler temperatures, we are surprised by our lack of comfort. In order to cool, perspiration must evaporate. In the nearly saturated air beneath the canopy, water can only barely evaporate. The open field, even with its hot, direct sun, may actually feel refreshing because of its lower relative humidity and strong evaporating breeze. However we suffer, the ferns and orchids, the salamanders and millipedes, the mushrooms and bacteria are all happy as clams on the forest floor (is that what they call a mixed metaphor?).

In a final gesture of sacrifice, it is the canopy that is struck by the full force of storms and suffers beatings administered by rain, sleet, and hail. The impact of huge drops of water falling from heights as great as 7 miles can be painful, to say the least. The absorptive capacity of trees for such an attack is well recognized. Where else do we go in a sudden storm, but into the trees? Delicate plants and animals, exposed soils, and valuable layers of detritus can all be seriously damaged by heavy rains and hail if left unguarded by the protective canopy of a forest. Like the sun and wind, the energy of these forces is also directed at the resilient canopy layer, sparing the more vulnerable strata beneath, the layers known collectively as the **understory**.

Although subject to the climate and variable weather of the region, the forest greatly alters these conditions beneath its protective umbrella. It produces its own microclimate. Although all parts of the region may experience essentially the same number of days of sun and rain, the same temperature extremes, and the same amount of snowfall, within the microclimate of the forest canopy the extremes are significantly moderated. Daytime high temperatures are not as high. Nighttime low temperatures are not as low. Humidities do not rise and fall as abruptly. Wind speed does not vary as much. Snow is not blown away as easily, nor does it melt as quickly. The actual climate under the trees is buffered.

Jon Hawker

The hot, dry environment of a Missouri glade allows scorpions to survive.

Microclimates allow the survival of a host of species that would otherwise succumb to the extremes of weather. The forest, then, is responsible for the creation of a particular kind of **habitat** (= a place to live), a word derived from the Latin *habitare*, meaning "to live." The species identified as forest dwellers are intimately related to and very much dependent on the alteration of climate by a canopy. This layer produces a forest microclimate and thus a forest habitat.

As one might suspect, there is always a downside. Not all of the effects of a canopy are beneficial. For plants with inefficient light-gathering tissues, like pines, junipers, many grasses, and most weedy plants, the shade can be lethal. For animals with high heat demands, such as scorpions, collared lizards, or coachwhip snakes, the protective canopy is equally inhospitable. None of these species is normally found in forests. Even the usual forest residents sometimes suffer from canopy side-effects. In a light rain shower virtually none of the water will reach the ground. Skinks search in vain for tiny droplets to lick from dusty leaves and stones, while box turtles remain dormant under the leaves, unaware of the passing storm. Meanwhile, the wet canopy leaves ineffectually evaporate the wasted rainwater back to the passing air stream.

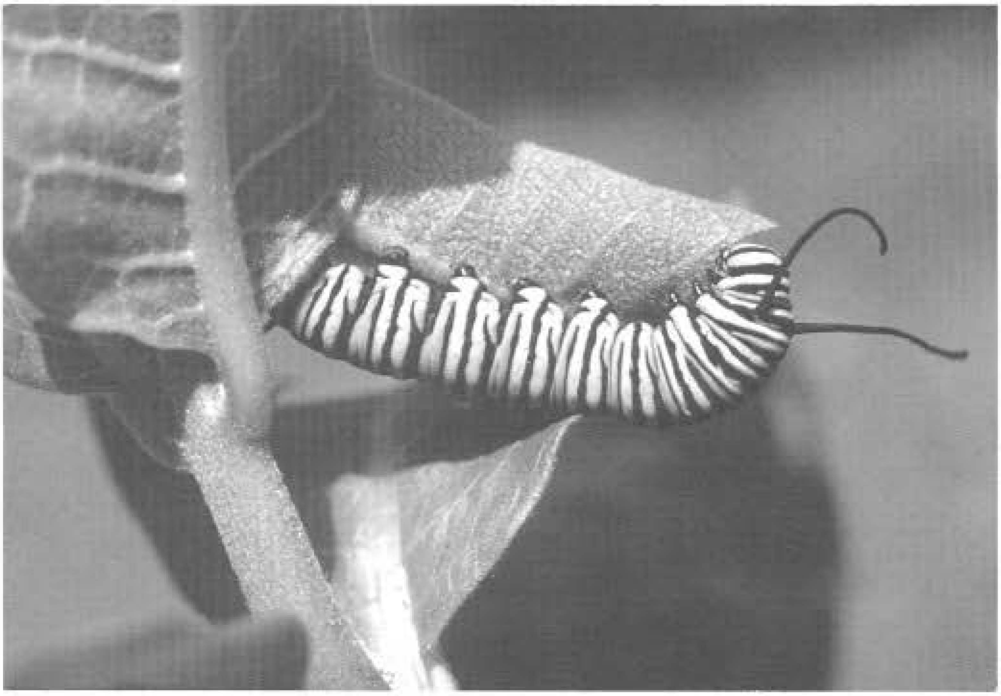
Prairies and fields have no large trees to form a high, dense canopy, and are dominated instead by soft-stemmed or herbaceous vegetation, collectively called grasses and **forbs** (herbaceous plants with broad leaves, such as ferns and wildflowers). For humans, standing tall, grasslands are alternately sunny and hot, cold and windswept, or decidedly unsafe as frightening thunderstorms roll in. At such times, we would rather be snug and secure in the shelter offered by a dense forest (ignoring the danger of being struck by lightning!). Even in winter, the trees of a forest provide some comfort, warming the air a bit by radiating absorbed sunlight, and reducing the chill by slowing the passage of the wind. Where, oh where is that shelter when one is stuck out in a prairie thunderstorm?

However, if one would only think small and put oneself into the world of the mouse or grasshopper, one could clearly see the similar degree of dominance exerted by these shorter plants over a dwarf world, one that is closer to the soil. To the mouse, the weeds are a high, dense forest and their impact on climate at ground level rivals that generated by trees. The grasses and forbs produce a comparable microclimate and habitat for a shorter, less visible world. While we cannot escape the wrath of a storm by burrowing into this microclimate, rest assured the mice and grasshoppers, the clumps of moss and tiny wildflowers beneath will pass through the assault relatively unscathed. Whether in forest or field, winter or summer, moderation of extremes is a key plant commodity.

Microclimates can be generated by a single plant as easily as by a whole bank of vegetation, although the moderating effects of the plant will be reduced in proportion to its size. For instance, a tree in a field will provide shade and create cooler ground temperatures around its base, even though it may have minimal effect on wind speed at ground level. Within its small canopy, however, even the flow of air is slowed considerably. An underwing moth resting flat on the tree's bark, or a summer tanager's nest on one of its branches are surely in more secure positions than a zebra swallowtail flying past.

The effects of a single wildflower are just as real, even though they are far less obvious or far-reaching as the tree's. Like a tree, a large-leaved plant, such as ragweed, cup plant, or burdock, or one with dense leaves, such as goosefoot, may create some shade on the ground, break the force of falling raindrops, and slow the wind, if only for a very small area. Still, such a minor effect may allow a grasshopper, spider web, or the funnel-like depression of an antlion to pass through a storm unscathed. More importantly, small grasses and wildflowers produce a multitude of favorable, although nearly invisible microclimates for thousands of tiny animals that are actually in direct contact with their stems, leaves, flowers, and fruits.

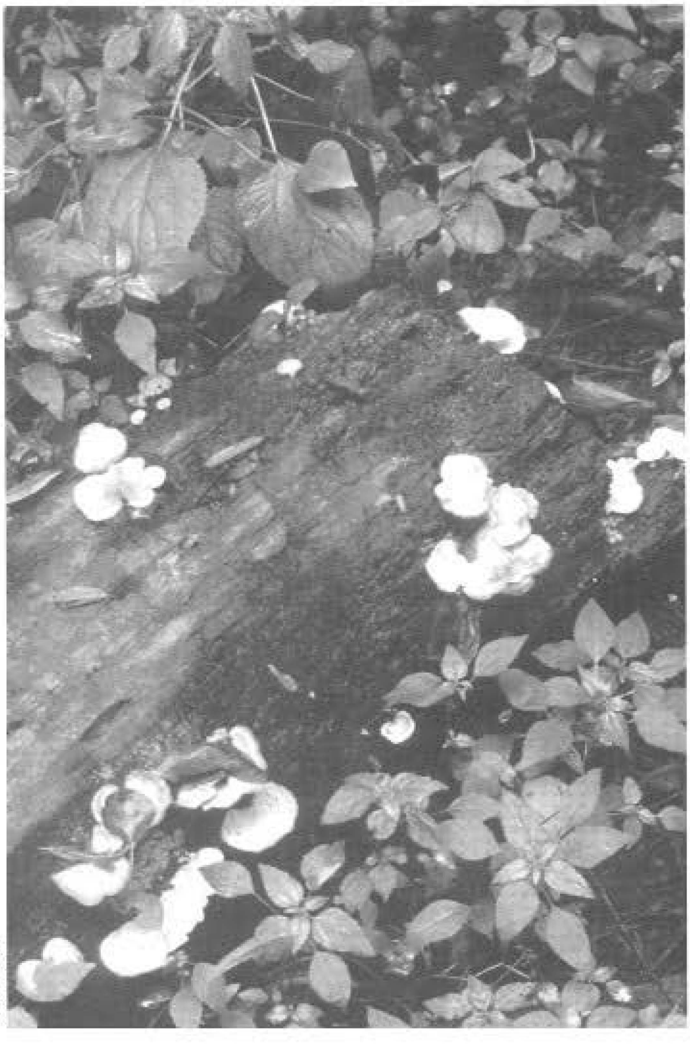
A single leaf can shelter a monarch caterpillar nest from the worst weather.



Jon Hawker

For example, aphids under a leaf are protected from the sun, wind, and rain, and thereby live in a totally different world than is available to a caterpillar feeding on the surface. A crab spider nestled in among the individual flowers of a goldenrod experiences less weather than a neighboring golden argiope exposed in its web. A flower beetle crawling around inside the tubular petals of a bellflower, or a moth in a yucca blossom both receive more shade and protection than a honeybee passing from one ironweed blossom to the next. The sheltered insects are warmed faster on a cool morning and cool more slowly in the evening. The dish-shaped petals concentrate sunlight inside the flowers, warm the air held there, and guard it against a chilling breeze. With the early start each day, the bugs sheltering within may grow faster, mature more quickly, and reproduce more abundantly.

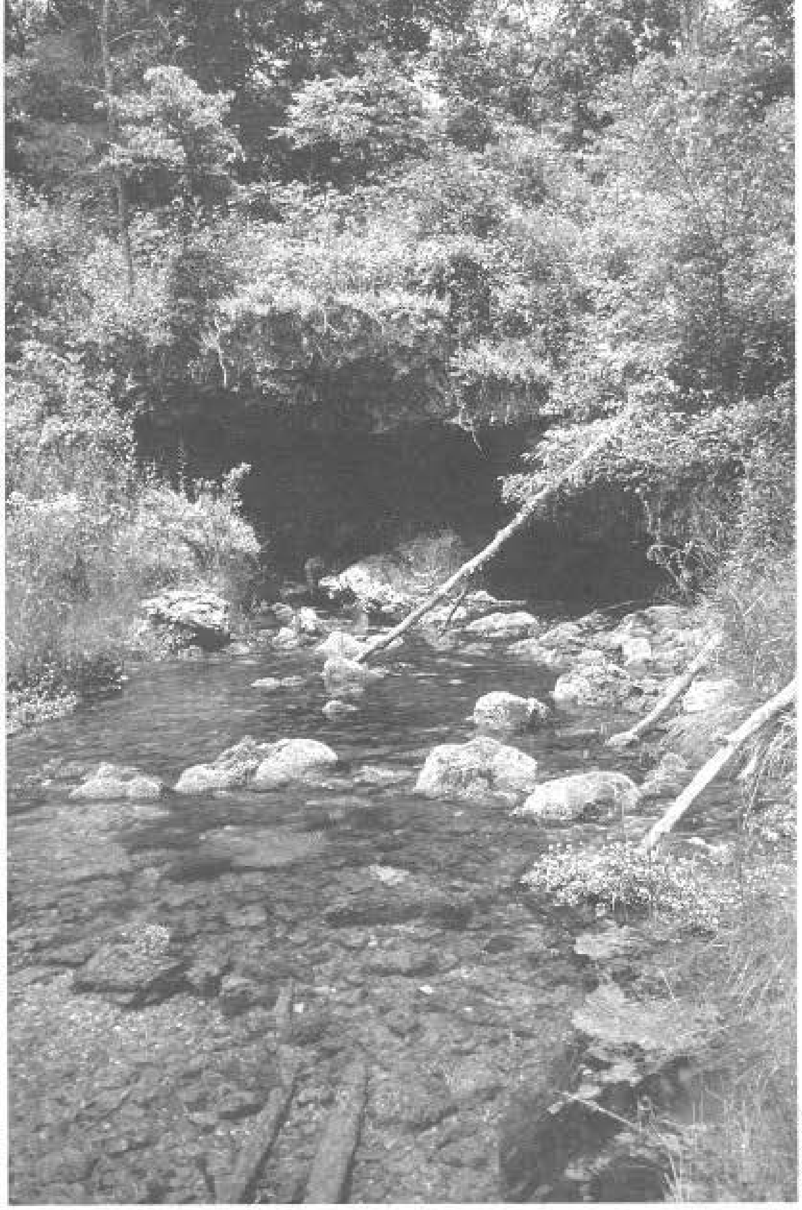
A fallen log can shelter thousands of small creatures with its protective microclimate.



Nick Decker

Living plants are not the only structures in the environment that produce microclimates. Dead plants also create microclimates and habitats. The layer of dead organic matter on the floor of the forest or grassland creates the same conditions as the weeds of a field or the trees of a forest, but in miniature. Instead of deer and squirrels, or mice and grasshoppers, the debris protects a community of beetles, spiders, millipedes, snails, mites, and worms. The detritus insulates the soil surface from temperature extremes, retains moisture, and shields its delicate inhabitants from the sun, wind, and rain, exactly like the canopy overhead. At the same time, like the canopy, the detritus provides food to its inhabitants. While the canopy feeds a food web based on green, growing leaves, the dead leaves on the floor supports detritus-feeders and their predators.

A fallen log provides yet another type of microclimate, one that is even more secure than the leaf litter on the forest floor. Dead leaves decompose in a few years and are likely to be blown away or carried off in a storm. Dead wood is heavy enough to resist movement and is slow to decay. A big log can offer animals shelter and food for decades. The log is less likely to dry out than the thin leaf litter and releases nutrients over a much longer period of time. The extra security created by such a stable environment attracts a greater diversity of organisms. Scraping the



Jon Hawker

Powder Mill Creek Cave, like many others, greatly moderates the climate around its mouth.

leaves aside on the forest floor reveals a rich biological world crawling with dozens of tiny creatures. Rolling a dead log exposes these and hundreds more, including spiders, harvestmen, mice, small snakes, lizards, and toads. This is why it is important that pokers and collectors put the leaves and logs back exactly as they find them. It may take a dozen years to create the special conditions under a log necessary to support these varied creatures. Turning a log or stone and not replacing it is tantamount to bulldozing a forest.

Even structures that have never been alive can create microclimates. The various **exposures** - the degrees to which sites are exposed to sun, wind, and rain - offered by hillsides are the largest, most obvious, and perhaps most important microclimates that we see in Missouri. The differences between north and south, and between steep and gentle slopes is crucial to the formation of many of our natural communities. However, the role played by geological features goes far beyond the mere production of exposures. Rocks hold heat and cold for long periods of time. A large boulder or bluff can absorb sunlight on a blustery December or January day and stimulate the flowering of nearby plants weeks or months before their relatives in the nearby forest. Later in the year, the bare, heat-radiating rock may protect plants from the harsh effects of a late frost. Even in the dead of winter, with the air temperature hovering just above freezing, fence lizards will emerge from hibernation for a few brief hours to lounge on the exposed faces of such natural solar collectors.

A cave mouth offers a particularly stable microclimate of cool summer air and warm winter air to any plant or animal unable to withstand sudden swings in temperature or humidity. The cool, moist rocks around the mouth of a cave support mosses, liverworts, salamanders, and snails that would perish a few feet away. The cave itself, although not a rich environment because of its lack of light and photosynthesis, is one of the most stable microclimates in the state. Most cave organisms could not possibly survive exposure to the rapid changes of temperature and humidity at the surface.

The springwater released by a cave offers a less stable microclimate than the cave itself, but far more constant than the creek nearby. Having first been cooled or warmed to the mean average annual temperature of the earth at that particular latitude, the springwater slowly warms in the summer or cools in the winter as it passes downstream. However, near its source it offers a unique, nearly changeless environment that is taken advantage of by a host of sensitive creatures, both plant and animal.

Though they are more changeable than a spring, creeks and rivers are less affected by temperature changes than the air around them, offering their plants and animals a more moderate microclimate than is available ashore. All bodies of water absorb and release large quantities of heat without changing temperature much and thus act as great insulators. Lakes, ponds, and marshes are far slower to warm in the spring, and far slower to cool in the fall than the surrounding countryside, thus protecting their communities from late or early freezing. Furthermore, the heat-absorbing and heat-releasing properties of a body of water extend to nearby terrestrial plants and animals as well as to its aquatic inhabitants. A good measure of the microclimate-producing ability of a body of water in air is to simply note where fog collects on moist nights, or where frost collects on a cold spring morning.

Snow melts quickly in the microclimate created by even a small spring.

Jon Hawker

Rocks are not renowned for their ability to absorb large volumes of water. During a rain, most of the water simply drains from a boulder or bluff. While this may not help plants and animals struggling to survive on the rock, it can dramatically increase the effective amount of rainfall for those dwelling in the surrounding soils. Instead of an annual accumulation of 30 or 35 inches of rain on the open ground nearby, the soil at the base of a large flat rock can pick up twice that amount or more. The gain can be comparable to the difference between Phoenix and St. Louis, or between St. Louis and the Smoky Mountains. Furthermore, because no plants live in the soil under the rock, there may be moisture available there for roots and burrowing animals long after the surrounding ground has dried in an extended period of drought. Plants next to a large rock, catching its run-off and sending their roots underneath, are often taller, greener, and more luxuriant than others struggling without the benefit of the rock's water-channeling and water-holding microclimate.

Microclimates and their resultant habitats can be of any size. To appreciate the tremendous diversity of habitats available in Missouri, we must remember that humans are big, almost the largest of all the state's animals; the bulk of Missouri's animals are less than ½ inch in length. For these animals, habitats need be no larger than a thimble to produce a comfortable, livable set of conditions. To truly appreciate the full spectrum of natural communities in Missouri, we must learn to think more like a bug.

Topographic features, rocks, logs, plants, and other structures can alter local conditions and create microclimates that allow plants and animals to survive in a region from which they would otherwise be excluded.

Changing Habitats

Missouri's simplest habitats, and at the same time those that are among the hardest to adapt to, are often those that have only recently been created. New expanses of bare rock exposed by geological uplift, volcano, erosion, or bulldozer are among the most austere environments in which to make a living. Alternately windswept, baked, drowned, or frozen, bare rock habitats demand unique approaches from the creatures that attempt to maintain a life on their exposed surfaces. Organisms use many mechanisms to conquer such harsh conditions. Whichever option is chosen, the presence of living beings on a bare rock surface modifies the developing habitat in predictable ways. The development of a community on bare rock, and the orderly sequence of more complex communities that in time replaces the original and each other in succession, is known as **primary succession**. New bodies of water also undergo distinct successional changes. Outlining these processes is a necessary prelude to appreciating our tour of the Missouri environment.

The first organisms to live on bare rocks are typically simple plant-like organisms, especially **lichens**. Commonly referred to as pioneer plants, lichens are usually the first organisms to pioneer and colonize such bare areas, but are not actually plants. Lichens are a close association between a parasitic fungus and a host alga or bacterium on which it feeds. In a remarkable balancing act, the single-celled algae

Jon Hawker

Although not actually plants, lichens are the first plant-like organisms to move onto bare rock.

or bacteria grow and reproduce rapidly enough so that they are not killed by the attacking fungus. While the species of fungi involved in lichen relationships are generally unable to live without their algal or bacterial partners, the alga or bacterium is usually a free-living species that has been captured and is imprisoned in the relationship rather unwillingly. While most lichens are not particularly fond of calcium-rich, alkaline dolomites and limestones, they develop in grand profusion on chert, granite, rhyolite, sandstone, and other hard rocks with an acid reaction.

A wide variety of organic compounds are released by lichens as they grow. These unique chemicals react in many ways with minerals found in the host rock surface, forming what are known as **chelates**. Similar organic-mineral chelate combinations are well-known and widely used by gardeners because of their solubility in water, and thus their availability to plants. Because chelating may lead to the loss of minerals from the rock surface, the presence of lichens may hasten the deterioration of stone. In addition, many lichens also secrete and store a chemical called calcium oxalate that reacts directly with the rock surface, causing it to disintegrate. Whether individual kinds of lichens actively attack the rock or not, they do hold moisture against the surface for a short period after each rain, which increases the dissolution of minerals in summer and the expansion and cracking action of frost in winter. All of these processes accelerate the breakdown of the rock.

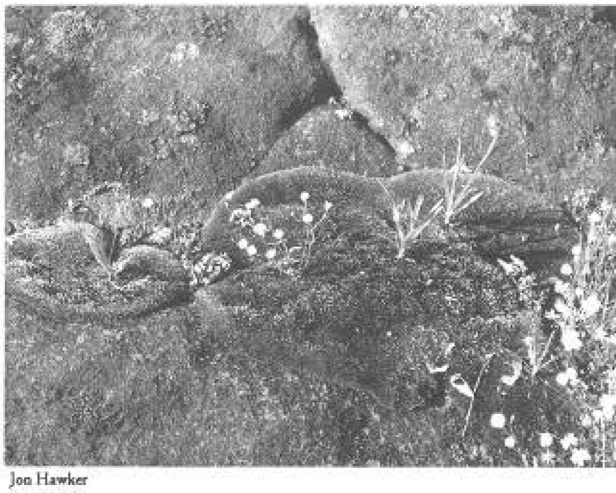
Tiny particles of silt and sand accumulate under the protective cover of the lichen body as they break free. Bits and pieces of organic matter join the mineral mix as older parts of the lichen die and disintegrate, forming a crust of blackish soil. Although nearly immeasurable, the thin layer of soil that collects may be adequate to support nearly invisible roundworms, mites, and other scavengers, and equally tiny predators such as centipedes and stingless pseudoscorpions. The living thallus or body of the lichen will feed a variety of small herbivores. For those of us without a hand lens, grasshoppers are the only noticeable vegetarians. These colorful, often noisy insects are stalked by wolf and jumping spiders that diligently search the crinkly forest for their leaping and flying prey. Because of lichens, then, a community has formed on what would otherwise have simply been an expanse of bare rock.

With the appearance of soil, no matter how thin, other organisms can take advantage of the changing conditions on the rock. Soon mosses may begin to establish themselves in the thin soil, the first true pioneer plants in the mix. Their spores have been carried onto the rock the whole time by wind and rain, but have either blown away or died. Now, with a secure foothold provided by the lichens, they may find things a bit more to their liking. With their densely-packed stems, a colony of mosses holds more moisture for a longer period of time, further accelerating the weathering process. Rock debris and organic matter build within the core of the colony and offer greater living space to mites and roundworms. Sowbugs, millipedes, earthworms, and snails churn and enrich the developing soil as they burrow. Fence swifts and other lizards scratch around the clumps in search of prey while taking advantage of the heat offered by the sunny exposure. The addition of the animal wastes and bodies as they die adds nutrients and the expanding community flourishes.

Eventually grass or goldenrod seeds, or fern or spikemoss spores may find enough substance for their roots. The tiny threads creep into the cracks and depressions in the rock as they seek sources of water and nutrients. Enlarging as they grow, the roots force the cracks apart, exposing a larger surface area to the physical and chemical mechanisms of weathering. The soil begins to build fairly quickly at this point and shrubs may take hold, followed by small trees. Gradually, a forest develops.

There is an orderly replacement process within each of the stages. One group of species changes the conditions under which it was originally able to grow, allowing another stage to succeed it. The pioneering group of lichens produce conditions unfit for themselves, but suitable for another stage. These eventually yield an environment amenable to mosses, which then shade, crowd out, and replace the lichens. Mosses permit sufficient soil development for the survival of

Moving in behind the lichens, mosses create and hold enough soil for small rooted plants.



Jon Hawker

Nick Decker

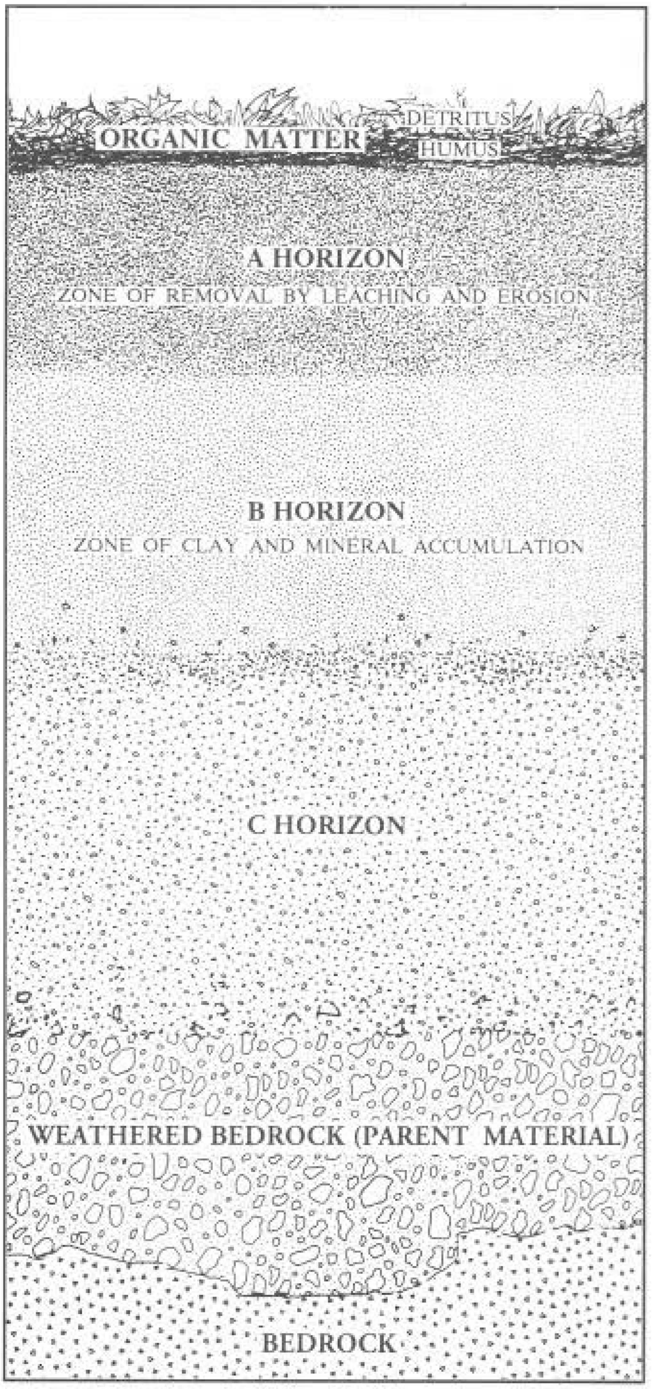
Massive, rounded granite boulders resemble a herd of elephants at Elephant Rocks State Park near Graniteville. A popular braille trail through the huge rocks allows the blind to experience the wonder of the unusual landscape.

grasses and forbs. These herbaceous plants gradually push out the mosses, much as the mosses had shoved the lichens aside. Competition for light, space, water, and nutrients continues as grass and forbs are ousted by the shrub stage, and shrubs are forced out by trees. With each stage come the animals that are dependent on that particular group of plants for food and shelter, so the entire community changes.

Species within each stage are able to sustain themselves on the thin, relatively depauperate soil they find, but increase its depth and fertility by their continuing presence. Other species are then able to survive in the improved soil and push out the creators. Finally, after thousands, tens of thousands, hundreds of thousands, or perhaps even millions of years, a group of species develops that is able to replace itself as well as all others for as long as the climate remains constant. Such a community is called a **climax**. The climax community is the end of the long, orderly replacement process called primary succession, whereby an originally bare rock area eventually supports a stable, self-perpetuating community. The slow process of primary succession may be viewed among the great boulders and rock exposures at Elephant Rocks, Johnson's Shut-ins, and Sam A. Baker state parks. Pack a lunch, because it's a VERY slow process.

Different soils and climates around the world result in the creation of different climax communities, dominated by different species of plants and animals. Even within a single biome a number of climax communities may develop. Eastern temperate deciduous forests are not all the same, for instance. Up north, the forest is dominated by basswood and sugar maple. To our east, beech and sugar maple predominate. Here in Missouri, largely in response to lower levels of precipitation, oak and hickory are the usual end products of primary succession. Yet, wherever an exposure creates a suitable microclimate, such as on a north-facing slope, sugar maple and basswood gain the advantage. Thus, climax communities result from a complex interaction of bedrock geology, slope, and climate, and are variable.

During primary succession, the soil also undergoes an orderly process of change, which occurs at roughly the same rate as the turnover of plant and animal communities. The end result of these changes is the evolution of characteristic **horizons**, or soil layers, that may be seen in a cross-sectional **soil profile** as we dig from the surface down to bedrock. A gradual change in the proportion of organic matter to mineral material, a measurable difference in the kinds of minerals present, and variations in the physical characteristics of the soil are each partly responsible for the distinctive appearance of each soil horizon. Soils of different ages or sources will each exhibit profiles with horizons of distinctive colors or thicknesses. In most ordinary soils the profile will grade from a horizon of pure organic matter at the surface, the layer of dead plant and animal material called **detritus**, to pure mineral material at some depth above bedrock.


DETRITUS
ORGANIC MATTER
HUMUS
A HORIZON
ZONE OF REMOVAL BY LEACHING AND EROSION
B HORIZON
ZONE OF CLAY AND MINERAL ACCUMULATION
C HORIZON
WEATHERED BEDROCK (PARENT MATERIAL)
BEDROCK

At the surface of most soils is a layer of detritus, called leaf litter in forest or thatch in grassland. Detritus is relatively fresh and consists of leaves, stems, bark, raccoon scats, acorn caps, beer cans, tissue paper, and so on. Natural detritus protects the soil from sunlight, wind, and drying, the direct impact of raindrops, and extremes of both heat or cold. In addition, as indicated earlier, it provides food and cover for a myriad of small organisms. Earthworms, millipedes, snails, and tinier organisms feed on the detritus and are in turn eaten by lizards, spiders, beetles, and other predators.

As the debris is consumed by animals, it is also attacked by bacteria and fungi. The crumpled leaves are often loosely stitched together by a pervasive white embroidery of digesting fungal strands. After a few years, the components of the litter or thatch lose their identity and are converted to a shapeless mass of crumbly brown organic matter, much like coffee grounds in appearance, called **humus**. The tiniest roots of trees and understory vegetation penetrate all parts of the humus in search of the minerals being released by the bacteria and fungi of decomposition.

Earthworms and other organisms mix the humus into the upper layer of mineral soil, producing the deep, dark brown layer adored by gardeners. Enriched by the presence of organic matter, this uppermost horizon is the chief storehouse of nutrients for the community's plant growth. Most of the biological activity of the community is found in this horizon and its associated organic matter. It is at once both the most valuable and the most vulnerable portion of the soil. Materials are **leached**, or removed from this zone by water dribbling through the soil, like drinkable coffee dissolving from the grounds. As in a coffee pot, the percolation of water downward through the humus and upper soil carries dissolved or extremely small particles of organic matter to deeper levels. As it responds to gravity, the water also dissolves minerals and transports clay from the surfaces of weathering rock particles.

The clay particles and minerals leached from the surface collect in a lower zone. The depth to which they will be carried varies from soil to soil and region to region, but they generally accumulate about as far down as the average rain will soak. This lower horizon is lighter in color than its upper neighbor, because much of the organic matter responsible for staining the soil will decompose in transit. It also has higher concentrations of clay and some minerals, such as calcium, iron, and aluminum. The darker, upper zone of leaching is referred to by soil scientists as the **A horizon**, while the lighter, deeper layer of accumulation is called the **B horizon**. The A and B horizons together constitute the **topsoil**. Below these topsoil layers lies a deeper horizon of weathered and partially weathered material, the **C horizon**, and below that the unweathered material from which the soil has been derived.

Removal of material from the surface of the soil by wind and water, the two most prevalent forms of **erosion**, is a natural process. Once a soil matures, erosion and formation generally exist in a state of dynamic equilibrium, maintaining soil depth while inexorably leveling the land. Under natural conditions, weathering tends to create new soil at about the same rate at which erosion carries it away. Over a thousand year period, a hillside may drop a few millimeters or inches in elevation, carrying its forest ever closer to sea level, but the depth of its soil will not have changed appreciably. After millions of years the hill may be completely eroded away, but the depth of its soil will have actually increased. This seeming paradox is nothing more than the work of gravity.

On flat ground or gentle inclines, the process of weathering will almost always outstrip erosion. If water cannot move, erosion cannot remove. There is no place for the products of weathering to go on level land except straight down, and the soil grows deeper and older where it lies. In such soils, leaching becomes the most conspicuous agent of removal, often carrying minerals, clay, and organic matter deep into the ground. Surface soils can lose significant amounts of calcium, phosphorus, and other precious minerals, and may become impoverished.

On the other hand, erosion will have a slight advantage over leaching on sloping land, resulting in much shallower soil. Erosion constantly removes the loosened material at the surface, exposing the bedrock to further weathering. The thin soil of a glade, for instance, never has a chance to age, because its oldest portions are always being swept downhill. Such a perpetually young soil will have a poorly defined profile because water runs off instead of percolating. There is hardly a C-horizon, and seldom even a B-horizon. Usually an

Severe erosion typically follows development.

Jon Hawker

organic-rich, nearly black A-horizon sits squarely atop the weathering bedrock. Because leaching plays such a minor role in this kind of soil, it may actually be richer in some minerals, like calcium and phosphorus, than the deeper soil at the bottom of the hill. While rich, it is extremely thin, holds little water, and dries quickly.

Any force that disturbs the protective blanket of detritus and humus at the surface of a soil will hasten erosion without necessarily accelerating the weathering process. Priceless topsoil and nutrients can be lost, reversing thousands or millions of years of soil formation. Missouri has a long, sad history of soil abuse going back over 200 years, to the earliest farming settlers. It may have actually started much earlier with Indian agriculture, but we have no way of assessing their soil husbandry practices. We do know that European-style farm management has led to excessive erosion of some of our most valuable topsoil layers. The end products of this erosion have been a decline in fertility on huge tracts of our most productive land, an embarrassing amount of silt in our rivers, and the formation of monumental gravel bars along our lovelier streams.

As soils age and deepen, the addition of minerals from the breakdown of buried bedrock becomes more difficult. Because the recycling of minerals back to the soil by plants and animals is never one hundred percent efficient - some is always carried off downstream - the small losses by leaching at each revolution of the cycle take their toll. Soils tend to age badly, losing their vital elements and becoming impoverished. Although this theoretically should occur in all soils, erosion usually interrupts the aging process by exposing new bedrock to weathering, thus releasing fresh minerals to the soil. This is why a soil is often described as being in a state of dynamic equilibrium. It is dynamic because it is always changing, but in equilibrium because soil production equals soil destruction and removal. However, some very old soils in the Ozarks approach an infertile, senescent condition in which destruction seems to have exceeded production. These very ancient soils are of

Fields left exposed for months can lose considerable amounts of soil due to wind erosion.

Jon Hawker

such great age that leaching and erosion have reduced the most valuable nutrients to extremely low levels. The slow rate of soil development on these hard rocks allows virtually all of their most valuable minerals to be carried off before more can be released. Pines seem to survive well, even thrive on such soils, but hardwood growth is slow and stunted, and the corn never grows "higher than a grasshopper's thigh." There is a general tendency for younger soils to be more productive.

Among the youngest soils in Missouri are those that accumulated during and at the end of the Ice Ages, the silt and mud that settles out along streams with each spring flood, and the deposits of organic matter that drift to the bottom of swamps, marshes, and sinkholes. Of these, the most widespread are the youthful soils generated by glacial action and its meltwaters. None has been in place long enough to have suffered erosion and leaching to the same extent as an Ozark soil. In fact, the uppermost layer of ice-generated soils, a mere 5,000 to 10,000 years old, is of unparalleled economic importance. Next in importance, but only because they cover less area, are the rich bottomlands along rivers and streams. Under natural circumstances, these benefit from the annual deposition of new soil at their surface. With this continual rejuvenation, bottomland soils are almost always the youngest in the Missouri landscape and potentially the most productive. For this reason, bottomland soils have been favored by farmers from prehistoric times to the present.

Regardless of the specific conditions or the type of community that develops, after thousands of years the physical environment and its life will generally reach some sort of equilibrium. Bedrock will create soil to replace soil lost to erosion, while releasing minerals to replace nutrients lost to leaching. Oaks will create acorns to replace oaks lost to age and disease. A climax community perpetuates itself indefinitely under stable conditions. Even over great intervals of time, a visitor to the forest will still see the community as it appeared thousands of years before. Once that community materializes and matures, only the individual trees change; the forest as a whole remains unchanged. As long as environmental conditions remain constant, the forest remains constant. However, the environment is not constant. Change is the rule in this universe.

Through an orderly process called primary succession, various kinds of living things occupy bare areas, generate soil, and eventually produce a mature community.

How Do Communities Change?

Colliding continents, invading seas, rising mountains, deepening canyons, and chilling glaciers continually alter conditions on the earth. Entire sets of communities - whole biomes - are replaced by ones better suited to the new conditions. This kind of change occurs in a geological time frame, that is, over thousands or millions of years, as measured by the periods and epochs of the geological time scale. Primary succession generally works in this same time frame. Entire cultures of humans can arise and vanish without noticing the differences in climate, landforms, or communities. As significant as such changes are, their incredibly slow pace generally escapes perception.

Intense and short-lived disturbances, on the other hand, can instantly alter conditions in ways that are clearly perceptible to all. A forest fire, flood, or tornado may level a 10,000-year old climax community in a wink. One person with a chain saw or bulldozer can reverse centuries of balance and stability. But, as disastrous as such disruptions might seem at first, recovery from such disturbance is seldom as tedious as the initial process of primary succession that led to the climax. Nor is the destruction of an old balanced system always detrimental. In fact, there are many kinds of plants and animals whose very existence depends on just such a disturbance.

Most violent disruptions, natural or manmade, remove vegetation but leave the soil. Since it is the plodding pace of soil generation that retards the enlivening of barren rock and slows the creation of a mature climax community, the recovery process after such a disturbance is comparatively fast. With soil still in place, the constant bombardment of a freshly-cleared area by seeds quickly reestablishes a broad mix of plants. Blown by wind, carried by water, and transported by animals, the germ of a climax community arrives a parcel at a time from surviving stands. Herbaceous and woody species alike are well represented in this random delivery system. With unlimited sunlight, enriched soil, and monopolized water supply, the new seedlings streak skyward, initiating the process of **secondary succession**.

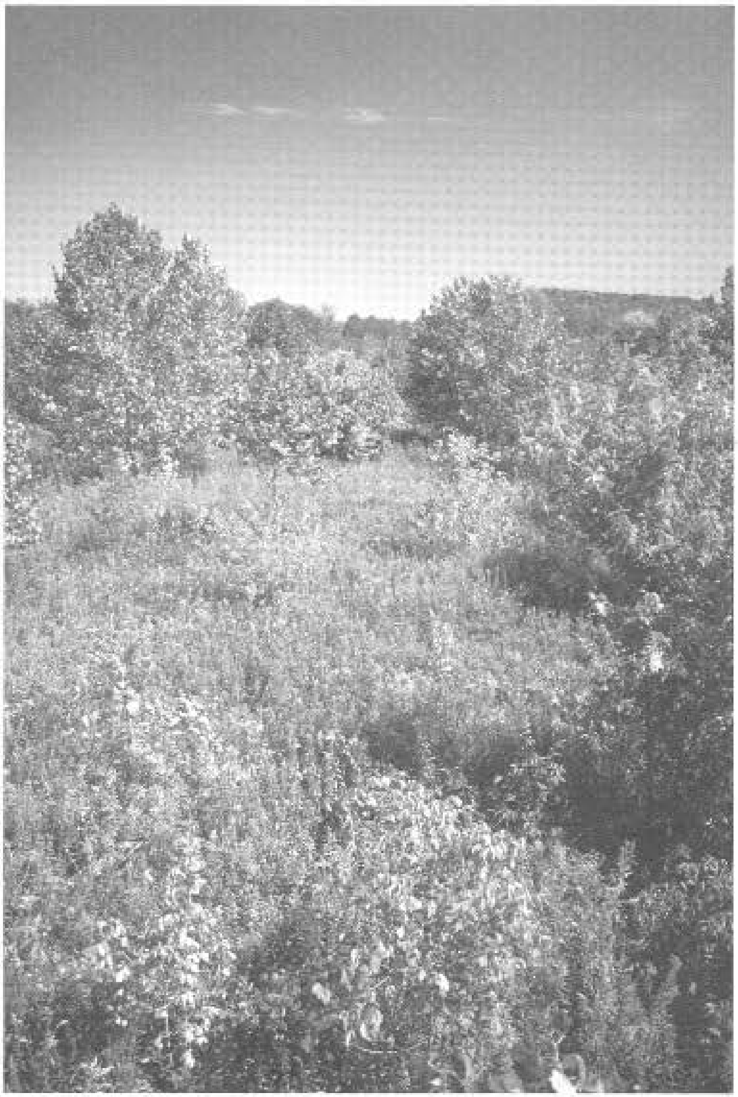
The first to appear are the sprinters, the **annuals**. Arriving by air are the puffy seeds of horseweed, fleabane, and sow thistle. These sprouts must compete with young tickseed, beggar's ticks, and hedge parsley carried in on the fur of animals. Maturing in a single growing season, and before they die, the annuals release an immense number of seeds to ensure the survival of future generations. Because they depend on vacant land for space, water, and sun, this huge mass of easily transportable seeds assures that these fugitive species will find another disturbed site the following year. We call them fugitive species because they are always on the run, constantly on the look-out for a freshly disturbed site. Annuals are forced into this gypsy lifestyle because they are quickly ousted by other plant species that stake a more permanent claim to the soil.

The seeds of **biennials** and **perennials** sprout alongside the annuals, but approach life with a different survival strategy. Mullein, thistle, Queen Anne's lace, wild lettuce, and other biennials make no attempt to capture the sky in their first year. They leave the sun to the annuals. Instead, the biennials patiently store large amounts of nutrients and energy in a heavy root system, then lie dormant over the winter. Using these food reserves in their second and last season, they bolt toward the sunlight. Spared the time-consuming task of sprouting and rooting from seed, they quickly overshadow the second generation of still-tiny annual seedlings. Supplied by a mature root system, the biennials stretch for the sky with tall flowering stalks, robbing the sprouting annuals of both light and water. The infant annuals starve and die.

Perennials operate in much the same fashion as biennials, except their maturation periods are much longer and their life spans

A field of goldenrod represents one of Missouri's most familiar communities of perennials.

Jon Hawker


Jon Hawker

Sycamores, silver maples, and cottonwoods will soon crowd out the goldenrods as succession proceeds.

are indefinite. Theoretically, perennials may live as long as trees. Like biennials, perennial goldenrods, ironweeds, asters, bonesets, and yarrow establish themselves in the soil before conquering the air. Spreading by underground stems and producing a massive root system, many species may not bloom for years. However, this patient strategy becomes its own reward, for the perennials will ultimately force out the straggling annuals and struggling biennials. After several years, with its territory secured, each mature perennial will bloom annually, releasing seeds to capture new territory, while maintaining a firm grasp on the old with a spreading base. The typical old field or pasture in Missouri is characterized by a mix of many native and introduced Eurasian weedy perennials. The domination of disturbed sites by a few aggressive species is typical of the perennial stage of secondary succession.

Although a number of woody species sprout and grow alongside the perennials, they remain masked by their taller, herbaceous neighbors for as long as 5 or 10 years. Cottonwood, box elder, slippery elm, and sycamore seeds blow in and are scattered about with the annuals and perennials. Winging in within the guts of fruit-eating birds are blackberry, coral berry, poison ivy, sumac, rose, black cherry, grape, sassafras, and eastern redcedar. Less randomly distributed, these seeds were initially encased in attractive and easily digested flesh. Passing through the animal's digestive tract uninjured, the seeds of these woody plants tend to accumulate along fence rows and power lines, or under the branches of nearby trees, wherever fruit-eating birds roost. In similar fashion, persimmon, grape, and other seeds are likely to be scattered along the trails utilized by raccoon, opossum, skunk, fox, or coyote.

Not in the least hindered by their passage through a gut, most of these plants actually have higher germination success when their tough seed coats are softened by digestive processes. Joining forces with the wind-borne "weedy" trees, they quickly overshadow herbaceous vegetation. Trees and shrubs have an advantage over the grasses and forbs each spring, for they need only leaf out from existing stems, while the perennials must send up whole new shoots. Sun-loving perennials ultimately lose this race for light.

Sumac, poison ivy, coral berry, and blackberry spread throughout the field by sending out hidden stems and roots, choking out other plants as they go. The ever-spreading crowns of fast-growing trees cast shade on the plants beneath. After several decades, a dense young forest will completely obscure the few surviving perennials, biennials, and annuals. With their low tangle of branches and stems, these woods are not for strolling. However, rabbit, quail, and deer find abundant food and shelter in these temperate jungles. In time, a few individual trees will climb above their nearest competitors and the shrubs and slower-growing, sun-loving trees will die. Very few perennials and seldom an annual will survive the thievery of light to witness the tyranny of these few fast-growing trees over their neighbors. During the process, a thin layer of leaf litter will reclaim the surface of the soil, slowly altering the detritus food web, once dominated by thatch-loving species typical of the perennial stage.

The abundant seeds released by the dominant species of this first tree stage will not reach reproductive age within their own short-lived forest. Although the cottonwood, sycamore, black cherry, eastern red-cedar, and others that temporarily control the jungle reproduce valiantly, their tiny sprouts quickly succumb in the shade of their elders. Like the annuals, biennials, and perennials before them, each of these trees requires full sunlight, and they are doomed unless they can reach a new disturbed site.

From the beginning, acorns and hickory nuts have been carried in and buried by forgetful squirrels or regurgitated by wandering blue jays. Sugar maple and basswood seeds have blown in from some distance away. Although they are extremely slow growing, the seedlings and saplings of oaks, hickories, sugar maple, and basswood are highly shade tolerant, well adapted to the lack of light in a forest. Their approach to survival is a form of patient nonchalance.

Untroubled by the temporary reign of sycamores and cottonwoods, each capable of several feet of new growth in a year, the oaks and hickories add mere inches each season, but endure. The fast-growing trees that colonized the area will die soon and leave few progeny in the developing forest. As each sycamore or cottonwood dies, the waiting oaks and hickories race each other into the vacancy. Many of these small oaks and hickories may already be 50 to 100 years old when they finally have an opportunity to stretch into the canopy.

Within a few decades small trees will reclaim disturbed land. Eventually a mature forest restores disturbed land to its original condition.

While their initial growth was slowed and stunted by the depressing shade of the short-lived trees overhead, within a few short decades, spurred by the sun, the dwarfs will reach canopy height and make their own rules. In turn, sugar maple and basswood pull the same stunt on the oaks and hickories.

After several or many centuries of continued growth, a mature climax community will conceal all trace of fire, flood, or axe. Because the soil usually remains after a disturbance, the redevelopment of a climax community through secondary succession is much faster than the establishment of a mature community through primary succession. Secondary succession needs neither the slow pioneer stage of lichens and mosses, nor the drawn-out physical and chemical weathering of rock. It begins with soil already present, fast-growing annual grasses and forbs, and succeeds to a self-replicating community in a single millennium or less.

Forest is not the only participant in the process of secondary succession. Grasslands also maintain themselves with a degree of balance over long periods, although they do not reach true climax conditions in Missouri. The very presence of prairie in the eastern and midwestern states is almost always the result of regular burning and grazing. Most eastern grasslands, Missouri's included, are in climatic zones with sufficient rainfall to support a forest climax. Over the millennia, the trees were ousted or pushed back by constantly grazing buffalo and by periodic Indian or natural fires. Our tallgrass prairie is essentially the perennial stage of secondary succession held in check indefinitely by fire or grazing. Such a community, kept from reaching the climax state by periodic disturbance or some other factor, is called a **subclimax**. Remove the source of disturbance, as has happened all across our prairie counties with the advent of fencing, road building,

Jon Hawker

and agriculture, and the perennial grasslands that remain are slowly swallowed by forest.

The prairie subclimax has its reversals, as does forest. In the past, millions of buffalo trampled and wallowed their way across native grasslands, gouging and tearing the perennial sod. Today, prairie dogs in the West, and gophers everywhere continue to dig up the vegetation in one area and bury it in another. Gophers even eat the larger rootstocks, speeding the deterioration of the sod. The burrowing activities of these reclusive rodents may turn over the entire surface of the soil every three years. In addition to enriching the soil by plowing under enormous quantities of organic matter, the destruction of the established turf allows annuals to carpet the soil with a profusion of blooms. Such a disturbed site among the dense sod of perennials permits annual species to thrive where they could not otherwise compete with perennial growth. Annuals often constitute as much as 70 percent of the vegetation in this kind of disrupted area. In fact, some annual species may be completely dependent on the recurrent minor devastations of small mammals for their survival.

Although the past half-century of natural community management philosophies have largely revolved around a policy of total protection, most researchers and management agencies are beginning to see the value of periodic disturbance. A great many plants and animals owe their existence to an environment in disarray. Annuals, biennials, and perennials, as well as many fast-growing tree species, and the animals that depend upon them, evolved with the rapid growth, prolific reproduction, and efficient dispersal mechanisms to capitalize on the ravages of fire, tornado, and flood. They are ill equipped to survive the order and balance of an aging ecosystem. Consequently, if we are to preserve the prairie, glade, and savanna

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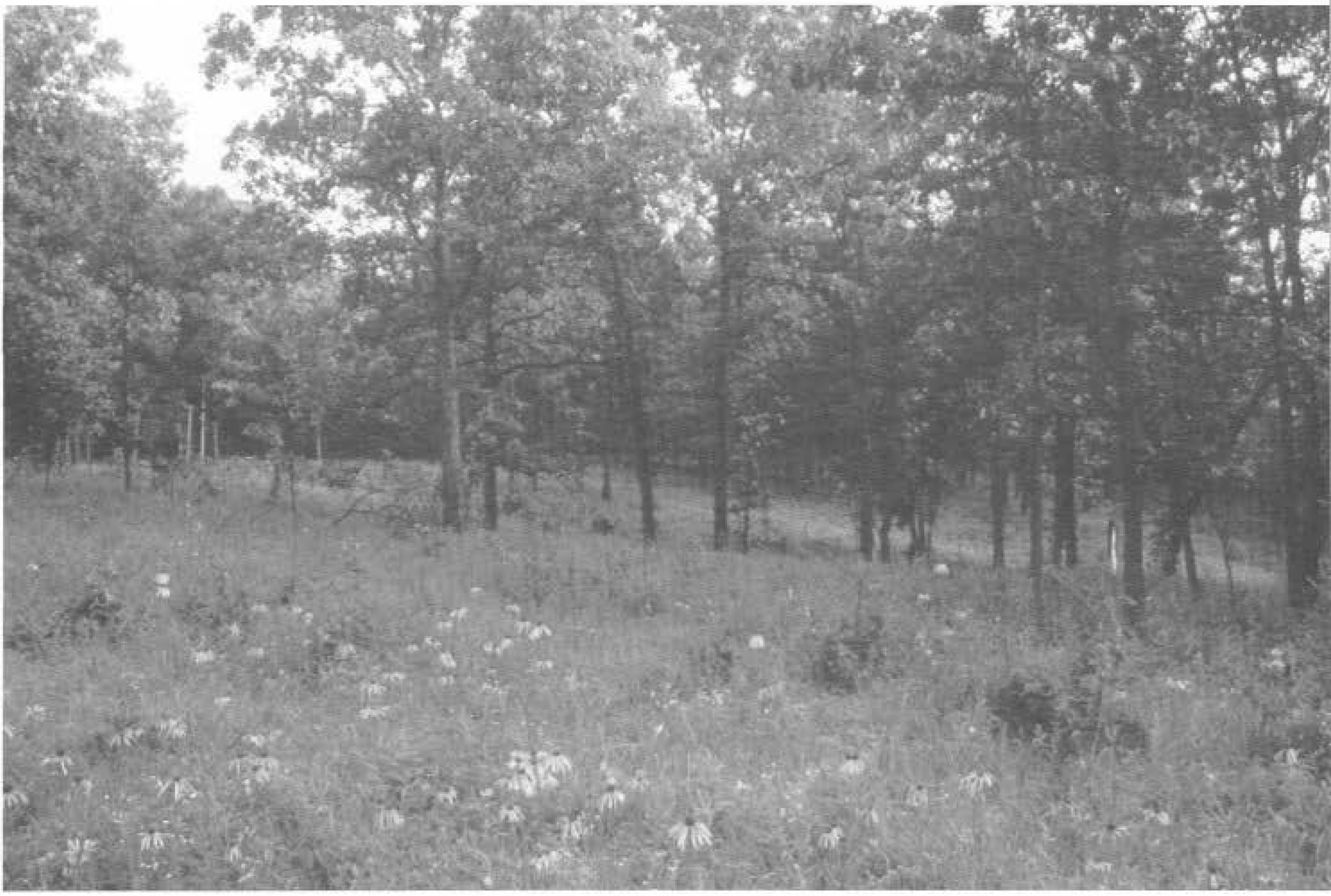
A carefully managed fire can control underbrush and encourage grasses and forbs, without injuring trees.

communities that existed when Europeans first arrived in Missouri - we must occasionally - but carefully, burn a forest to open its understory to the annuals and perennials forced out as shrubbery and small trees moved in. The Missouri Department of Natural Resources actively maintains the savanna and prairie communities that covered much of the state prior to European settlement using carefully timed and controlled fires. These rejuvenated or recreated communities may be observed at Ha Ha Tonka, Cuivre River, Pershing, and Prairie state parks. Nor is the habitat diversity created by the presence of additional species the only benefit delivered by disturbed communities. A young ecosystem, one that has recently recovered from some type of disturbance, also produces much more organic matter, much more food for animals. It is true that the total number of tons of organic matter, called the **gross productivity**, is generally higher in a mature forest than in a regenerating forest. However, from year to year there is no measurable difference in the total amount of organic matter in a mature forest. There are X number of tons of trees, shrubs, and animals today, and there will still be X number of tons a century or 10 centuries from now. As new growth occurs it is balanced by the death and decomposition of old growth. Over the centuries, the change, called the **net productivity**, remains very small, often zero.

Net productivity may be viewed as the profit generated by a community. Animals are smart not to live off the gross productivity of their communities, just as businessmen are wise not to live off their capital. Both are better off harvesting only the gains, the profit or net productivity. There is far more profit for herbivores and carnivores in a growing, expanding, and developing young community, than in an old, stable, mature community. This is one reason we never had an eastern hero called "Deer Bill." It was our vast productive prairie, not our forest, that supported North America's greatest herds of animals, the buffalo. For this very same reason humans live on the products of constantly rejuvenated fields of annuals - corn, wheat, and soybeans - and not stingy forests. All the plant matter in the cornfield at the end of each summer is profit or net productivity. It was not there in the spring, but is there to be harvested at the end of the season. A cornfield may not have much total organic matter, but it's all biological profit. There is a huge amount of organic matter in the forest, but try to feed 260 million Americans with the products of a forest. It cannot be done.


Jon Hawker

Wild flowers and grasses move quickly into a forest after a prescribed burn.

Fire, wind, and flood are natural calamities that destroy mature communities and reopen the soil. Annuals are a natural recovery system in such places. Without adequate razed sites, many valuable and attractive annuals, their companion perennial and woody species of secondary succession, and a multitude of animals species, are lost to climax growth. This is not to say that an old, beautiful forest should be axed or bulldozed to reestablish a young system of annuals just to gain its high net productivity. Neither should an old, balanced prairie be plowed. On the contrary, pristine natural landmarks like these deserve every measure of protection humanly possible. The species adapted to such climax and subclimax communities need far more attention these days than those of disturbed communities. After all, there are far more disturbed communities than undisturbed. However, in those instances when natural catastrophes cause what seems to be irreparable damage, we must keep in mind the natural healing processes of secondary succession. We must remind ourselves of the many species, the whole communities that benefit from natural disturbance.

All natural systems are subjected to disturbances that can destroy the mature community, but most are capable of regeneration by an orderly process called secondary succession.

What Do We Call Natural Communities?

Biologists need some system by which they can name communities that they and all of us can understand. As difficult as it may be for us to believe, community biologists have arrived at no absolute, fixed list of named communities on which all can agree, even after years of study and research, publication and argument. Many competing schools of thought exist. As biologists travel from state to state, and from country to country, they seldom find the local natural communities designated by exactly the same sets of terms used back home. However, there are some general terms that are widely accepted and understood here in Missouri.

On the basis of their dominant vegetation and stage of development, Missouri natural communities may be more or less conveniently divided into a number of major categories, including:

1. **Forest**, a community dominated by large trees whose canopy shuts out 80-100 percent of the sky, and with a variety of understory trees, shrubs, vines, grasses, and forbs.

2. **Savanna**, a tree-dominated community with a canopy cover of 10-80 percent, and an understory in which grasses and forbs tend to predominate. Parks and yards are often savanna-like.

3. **Prairie**, a grass- and forb-dominated community with very few trees or shrubs. A naturally-occurring community and not the same as an old field dominated by introduced weedy plants not native to North America.

4. **Primary**, a community at a very early stage of primary succession, such as a bluff, its talus slope, a glade, or a gravel bar.

5. **Wetland**, a water-dominated community of grasses, sedges, and forbs (such as seeps, marshes, and bogs), or of trees and/or shrubs (and therefore called a swamp).

6. **Cave**, a lightless community with a detritus-based food web.

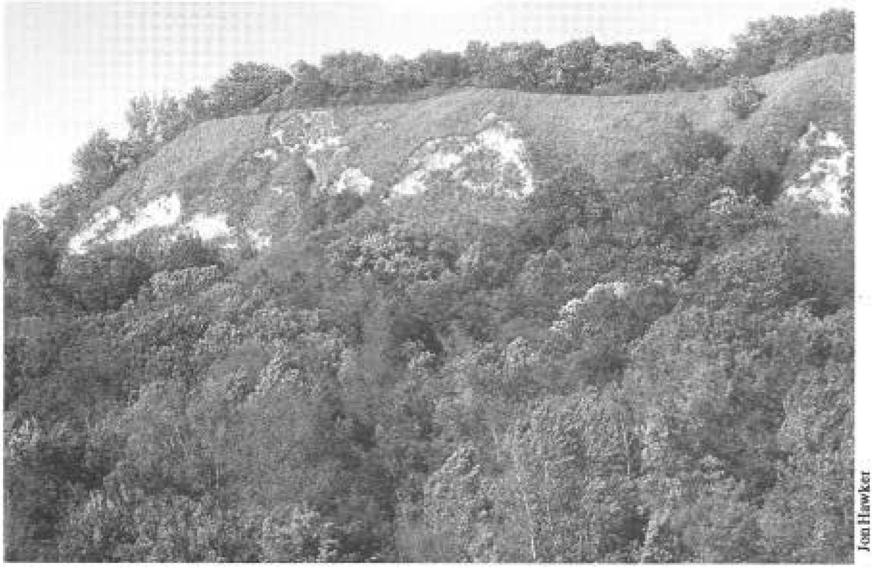
7. **Lentic**, an open-water community that is relatively stationary, such as a puddle, pool, pond, or lake.

8. **Lotic**, an open-water community that is flowing, such as a stream, river, or spring.

9. **Secondary**, a community created by disturbance, such as in burned, flooded, or storm-damaged areas, and dominated by annuals, perennials, or shade-intolerant woody species. This includes what are known as **cultural communities**, those created or maintained by human disturbance, such as pastures, roadsides, yards, parks, and other developed lands, now often dominated by foreign species.

Each of these categories may be more precisely subdivided on the basis of other important characteristics. For example, we further describe terrestrial communities, such as forests, savannas, and prairies, by the moisture regime in which they develop, labeling them xeric forest, dry forest, dry-mesic forest, and so on. The annual rainfall of the region, the exposure, and soil of a site all greatly influence the amount of water available to its plants. Hot, sunny, windswept glades on steep, south-facing, rocky slopes in the Ozarks may be desert-like during much of the year. The plant and animal mix that forms in such extremely dry situations are referred to as **xeric** or desert-like communities. If they are not actually desert species, the drought-tolerant or **xerophilous** ("drought-loving") plants and animals inhabiting such places will likely exhibit a number of xeric or desert adaptations. With increasing amounts of available moisture - a result of some combination of higher amounts of rainfall, deeper soil, diminished slope, and/or a more sheltered exposure - a **dry** site will result. Less desert-like, this community is more likely to have trees. Its grasses will often be taller and closer together than in a xeric community. For example, a loess bluff of northwestern Missouri has an exposure that is as hot, dry, and windswept as any south-facing rocky hillside in the Ozarks. Yet it will support a somewhat richer grassland community because of its deep, silty soil.

Surrounded by forest, the steep, windswept bluffs of loess in northwest Missouri are almost desert-like.



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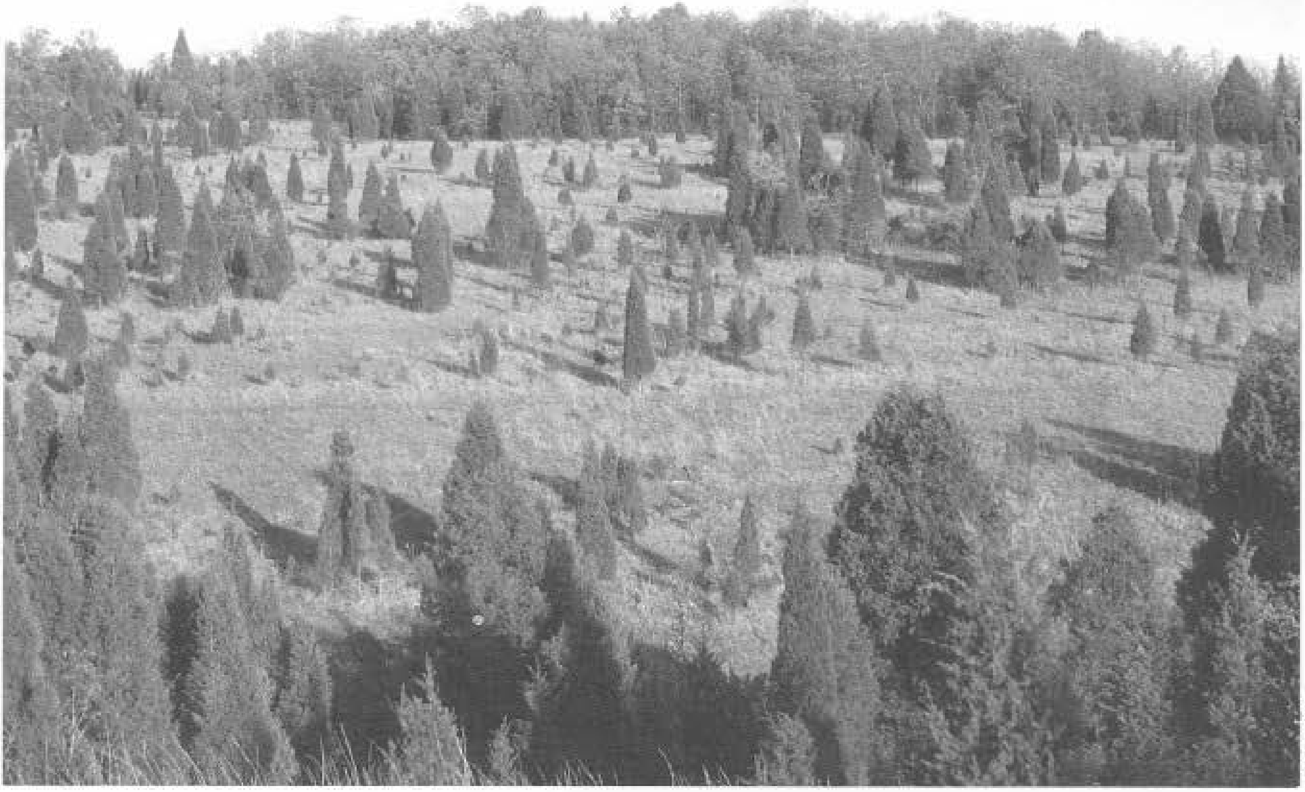
As moisture levels increase on more favorable slopes and soils, an intermediate **dry-mesic** microclimate, and then a **mesic** set of conditions will be produced. Mesic refers to a medium or moderate amount of moisture. Mesic sites are moderately moist, with average water availability, and are neither too dry nor too wet. Most broad-leaved forests in Missouri have formed under mesic conditions. Ridges and slopes, however, may support dry or dry- mesic forests. **Wet-mesic** forests generally occur along rivers or in other areas subject to periodic flooding of short duration, but where drainage is swift enough to allow some upland species to survive. Forests classified as truly wet are flooded or have saturated soil much of the year, but generally dry up at the surface by the end of the summer growing season.

Finally, a site that is always flooded or has saturated soil very near the surface all year will support a community of **hydric** or **hydrophilous** (water-loving) species, that is, plants adapted to living in water year-round. These wetland communities, such as swamps and marshes, are also often referred to by the term **palustrine**, from a Latin term that refers to swamps.

Because a forest on a dry limestone site will be dominated by one group of species, while the forest that forms in a similarly dry sandstone or chert location will consist of others, each moisture regime must be characterized more precisely by taking the underlying rock type or **parent material**, the material from which the soil is derived, into account. Thus we also describe communities by the terms igneous, sand, bottomland, chert, sandstone, limestone, or dolomite to differentiate the soil types involved. We end up with short, descriptive phrases such as dry sandstone savanna, mesic limestone forest, and wet bottomland prairie.

While this system sounds like it should be fairly straightforward, its arbitrary nature becomes really obvious when used in the field, as will any effort to pigeonhole nature. Out in the field, we are seldom lucky enough to find those convenient red or black lines that divide one community from another on a map. The differences between mesic and dry-mesic, or xeric and dry, are usually not immediately obvious, especially without a good deal of experience. Soil, slope, moisture, and vegetation differences all fall along gradients, merging and blending, seldom with the clear demarcation one might hope for. Nevertheless, the system serves a useful purpose.

Near the central part of a particular community, where environmental conditions become more clearly representative of that community type, its species mix also becomes more typical.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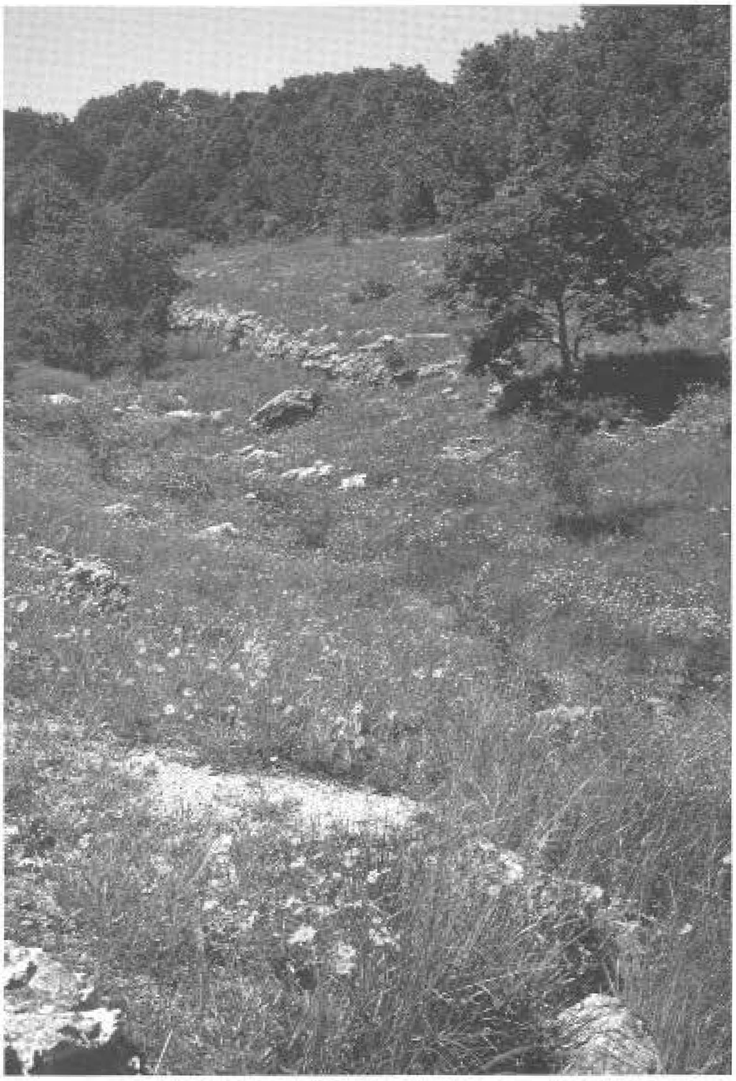
Junipers, or eastern red-cedars, move into a dolomite glade in Jefferson County along the layers of bedrock, where water is most available.

Whether in our mind's eye, on the written page, or in a photograph or drawing, it is generally possible to create an impression of each of these communities, even if the ecotone between the individual communities clouds the image.

For the person traveling around the state, whether driving, floating, or hiking, such a classification scheme may be confusing. Without years of formal training and experience to draw upon for rapid identification of species, rock types, soil characteristics, microclimatic conditions, and moisture regimes, a casual forest visitor may feel overwhelmed and never even attempt to examine the surroundings critically. Don't despair! Almost anyone can quickly and easily formulate a pretty accurate opinion about the rocks, soils, vegetation, exposure, and moisture regime around them through some very simple observations. Pause a moment and ask yourself a few sensible questions. Sensible, because you must use your senses.

For instance, is it a struggle just to stay upright as sweat burns into your eyes, or is the journey light, pleasant, and requiring little effort? Is walking limited only by an occasional branch or fallen log, or have you been crunching along between stubby little trees hung with sticky masses of spider webs, with unbreakable branches whipping your face? Has there been a pleasant breeze the whole time, has it been shady, or does it feel like the sun is about to claim its next victim?

Have you been stumbling blindly over half-buried stones that tumble away each time your other foot is lifted? Are the sharp edges of the sand and gravel that fill your shoes wearing holes


Jon Hawker

Perhaps Missouri's most desert-like communities, chert glades are found only in Jasper and Newton counties.

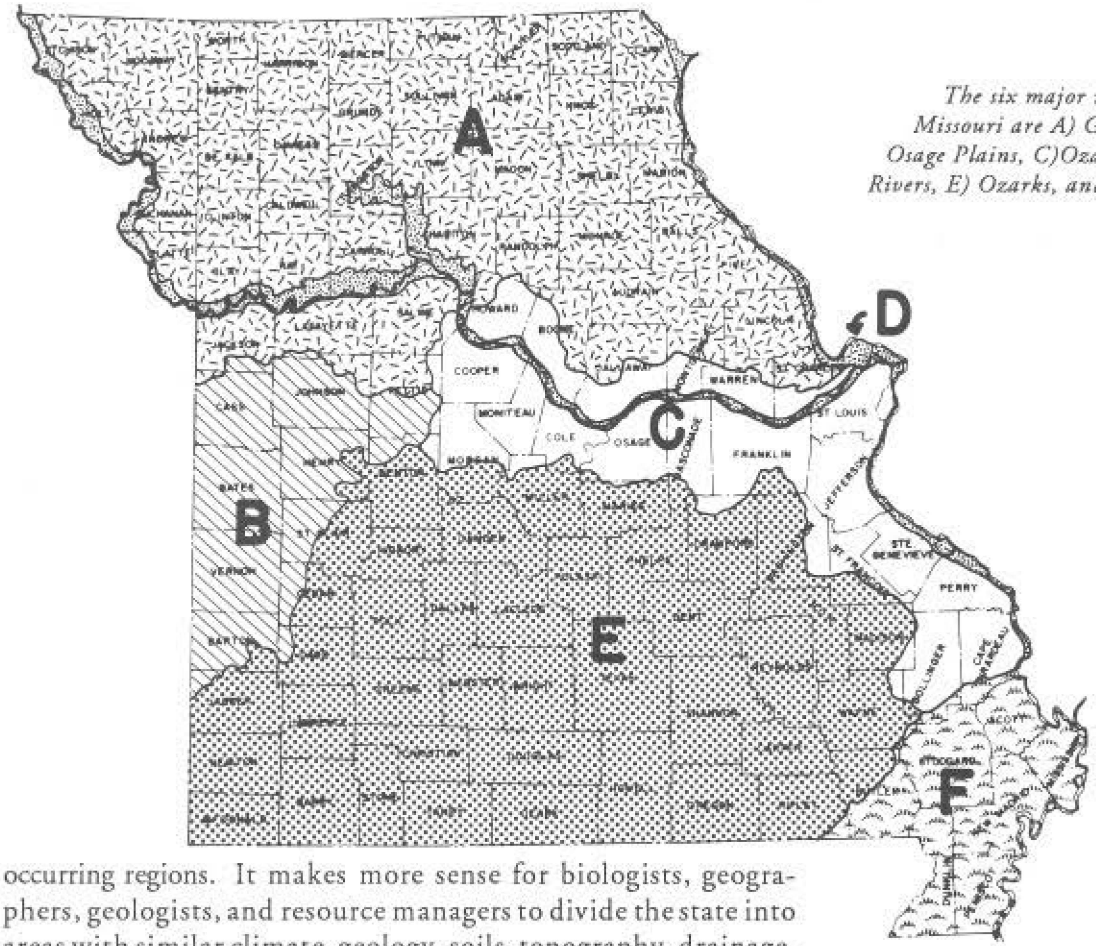
through your socks, or does the mushy black gook gurgling up between your toes feel soft and cool?

How about the water lapping at your ankles? Does it feel warmer than last night's chicken soup, or is it pleasantly cold and numbing the itch and pain of the last fly bite? Notice how nice the mud feels on your nettle-swollen calves, even though moving the 20-pound lump of mud on each foot has been a small victory.

Simple observations, but they can reveal much about the community being traversed.

Like the populations of which they are composed, communities also have certain requirements that determine where they will appear. A natural community that covers large areas will likely include species with similarly broad demands. A tiny community of narrow distribution will similarly be composed of species with more exacting requirements. Although most of our state is covered by a relatively few, very common community types, the diversity of rocks, exposures, and microclimates dispersed in regions with different climates and geological histories provides conditions for the establishment of a large number of unique, often rare plant and animal communities of special interest and pride for Missourians.

A number of our communities cannot be found outside a particular part of Missouri, although they may be found in adjacent parts of neighboring states. For instance, good examples of our unique shortgrass prairie community will only be found in Atchison and Holt counties in extreme northwestern Missouri. True chert glades occur only in Jasper and Newton counties of extreme southwestern Missouri. Igneous glades cannot be seen outside the St. Francois Mountains and its immediate surroundings. Many other communities are similarly restricted. To that end, a geographical system has also been devised in order to label the various regions of the state and to catalog which communities they possess. Counties can and often are easily used to identify where certain communities may or may not be found, but since these are political boundaries, they often overlap naturally



The six major natural divisions of Missouri are A) Glaciated Plains, B) Osage Plains, C)Ozark Border, D) Big Rivers, E) Ozarks, and the F) Mississippi Lowlands.

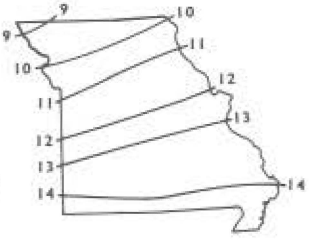
occurring regions. It makes more sense for biologists, geographers, geologists, and resource managers to divide the state into areas with similar climate, geology, soils, topography, drainage, and biological distribution.

When these many variables are combined on one map, it becomes apparent that Missouri may be conveniently divided into six major **natural divisions: Ozarks, Ozark Border, Mississippi Lowlands, Osage Plains, Glaciated Plains,** and **Big Rivers**. These divisions may be fairly easily distinguished, since each tends to have somewhat uniform characteristics throughout. However, based on minor local differences in the same criteria used for outlining the divisions, natural divisions may be subdivided into 16 **natural sections**. The six natural divisions and their 16 natural sections are outlined on the accompanying maps. Throughout the rest of this book, these will be referred to whenever appropriate.

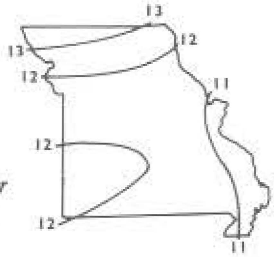
It must be remembered that just as biome and community boundaries are seldom clearly defined, neither are the borders of the natural sections and divisions. However, this geographical system, like the community classification system, is accurate enough to provide useful reference points for describing Missouri's flora and fauna in greater detail.

Missouri's natural communities are described and named by their moisture regime, underlying soil parent material, and dominant vegetation. The state itself is divided into six natural divisions and 16 sections taking plant and animal distributions, climate, and geology into account.

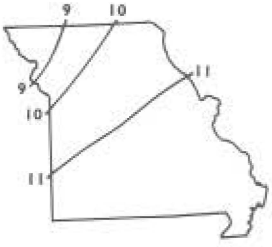
Are Missourians Really In The Temperate Zone?



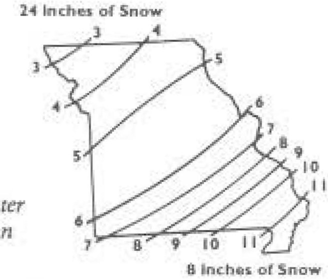
Average Spring Precipitation



Average Summer Precipitation



Average Fall Precipitation

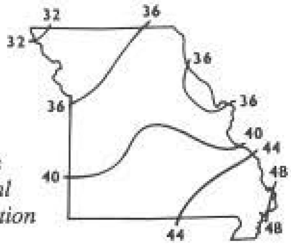


Average Winter Precipitation

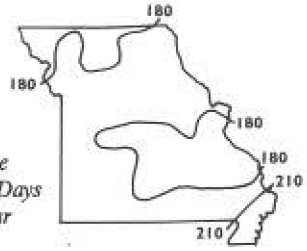
Of the natural influences that determine where biomes, natural divisions and sections, communities, and microclimates will be found, and what will result from the various processes of disturbance and succession, perhaps the most obvious is climate. **Climate** is a summation of the long-term weather patterns characteristic of an area, including year-by-year averages of rainfall, temperature, humidity, wind speed, and so on. Using standard climatic definitions, Missouri clearly falls within the temperate zone. However, simple average climatic data for a region can be misleading, because climate is more than just averages. Climate is also the day-to-day and seasonal variations and extremes of weather.

Missouri is centrally located and is far from the shelter of a great mountain chain or the moderating influence of an ocean. As a result, the state falls prey to the daily bickering of Arctic, Pacific, and Gulf air masses that meet unhindered in mid-continent and produce the highly unpredictable, feast-or-famine daily weather for which Missouri is famous. Some have even suggested that Missouri's climate is, in fact, most intemperate!

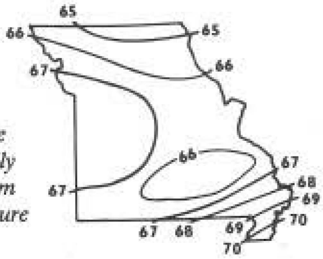
While some plants or animals may be able to thrive in a climate with exactly the same average conditions as are found in Missouri, the extremes of its seasonal changes conspire to limit what species are actually able to survive. For example, many kinds of delicate trees and shrubs do quite nicely in the Pacific Northwest or England, hundreds of miles north of Missouri, where average conditions are similar, but extremes are less noticeable. When planted here, those same plants are regularly devastated by our horrendous combinations of 100° F plus summers and subzero winters, early and late frosts, premature thaws, and droughts. Expert gardeners are often able to thwart Missouri's climate by taking advantage of the microclimates offered by buildings and massed plantings.



Mean
Annual
Precipitation

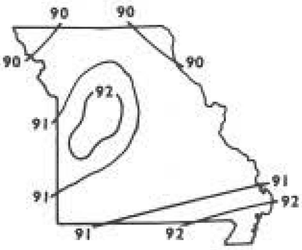


Average
Frost-free Days
Per Year



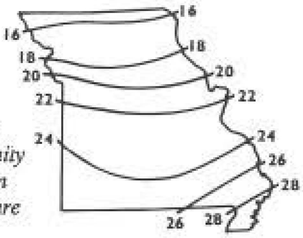
Average
July Daily
Minimum
Temperature

Fortunately for those excited by a diverse flora and fauna, Missouri's climate, while never predictable, is also not entirely uniform across the state. Nor has it always been as it is today. Average rainfall and temperatures rise sharply in the relatively short distance from St. Joseph to New Madrid. The markedly different environments of windswept Missouri prairie, forested Ozarks, and muggy Bootheel are the result of a strong temperature and rainfall gradient extending diagonally across the state from northwest to southeast.



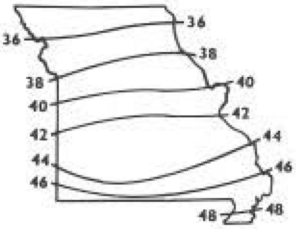
Average
July Daily
Maximum
Temperature

Mean annual average temperatures rise by roughly 10° F from the Nebraska border to the Southeastern Lowlands, while annual rainfall increases by nearly 2 feet along the same line. With less than 30 inches of rain each year and a cool 50° F mean annual temperature, the northwestern counties were ideally suited to the formation of grasslands, while bayou-like swamps and sloughs resulted from the warm, moist conditions in the southeast. Oak, hickory, and pine forests gradually replace grass and cypress along the gradient between these two extremes. In the past, quite different climates and quite different communities dominated our landscape.



Average
January Daily
Minimum
Temperature

While Missouri's climatic averages might suggest a similarity to the moderate temperate climates of England or the Pacific Northwest, its climatic extremes exclude many species that might otherwise survive within its borders. On the other hand, because climate does vary so greatly from the state's northwest corner to its southeast, representatives of many biomes are able to survive within its boundaries.



Average
January Daily
Maximum
Temperature

More Than A Melting Pot

Missouri is an unusual ecotone. Most border areas of biomes serve only as gradual boundaries and merely reflect the species composition of the regions around them. Missouri, however, is more than a simple biological melting pot. Within the state's borders is a distinctive group of plants and animals found nowhere else on earth.

Jon Hawker

This species of spiderwort, known as wild crocus, is not found outside the Ozarks.

For tens of millions of years the Ozark uplift has provided a fairly isolated highland in which species could develop entirely on their own. The Ozarks offered soil to some of the first flowering plants, witnessed the demise of the great dinosaurs, and nurtured the rise of birds and mammals. While these groups developed, the ancient uplift provided a number of unique habitats to which they could adapt. Over the millennia, some of these creatures adjusted to the rocks, waters, and climates found only in this island-like geological terrane.

Some of the more undemanding species have since been able to spread to other agreeable parts of North America. However, many have not and have become trapped in the Ozarks by various types of **barriers**, environments that, to them, seem hostile. A species trapped in an area by barriers is called an **endemic**. The Ozarks is rich in endemics, as are the Hawaiian and Galapagos Islands, New Zealand and Australia, and many mountains and deserts, among a host of other regions around the world, large and small.

A great many plants, flatworms, mollusks, crustaceans, insects, fish, and amphibians have become adapted to the cool upper stretches of spring-fed Ozark streams or the dark passages of Ozark caves. Such species as the Niangua darter, Ozark shiner, Ozark cavefish, grotto salamander, Ozark red-backed salamander, and gray-bellied salamander are not able to pass through the barrier of warm, murky waters in the swamps, prairies, and big rivers that flank the Ozark uplift. It has been equally difficult for Bush's skullcap or Arkansas beardtongue - beautiful native species especially adapted to the desert-like Ozark glades - to pass through the surrounding forest with its acid soils and meager sunlight. In contrast, many endemic forest species, such as the Ozark wild crocus (actually a spiderwort), Ozark trillium, and Ozark chinquapin (a type of chestnut), are limited to these same shady, wooded hillsides.

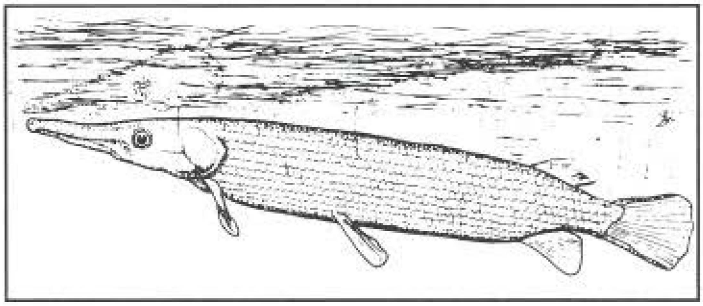
The same contrasting sets of environmental circumstances that bind species to the Ozarks may serve to deter infiltration into the highlands by outsiders. Pin oaks, diamond-backed water snakes, short-nosed gars, the tadpole madtom (a tiny catfish), and ghost shiners, for instance, are seldom able to intrude deeply into the upland. These species ring the Ozarks, filling downstream, downhill habitats that are equally off-limits to their upstream cousins. On the other hand, mammals and birds, more mobile and less sensitive to water and soil conditions, are seldom trapped in or excluded from the Ozarks.

Missouri provides many unique places to live, including the forests, caves, springs, and glades of the Ozarks. These offer special conditions to plants and animals, which, having adapted to them, may become trapped by their needs for those special conditions. As a result, the Ozarks has become home to dozens of endemic plant and animal species.

Breaking Through The Barriers

The Ozarks is not the only geographical entity to offer a special set of conditions to various kinds of plants and animals. The Big River System - the massive combined volume of the Mississippi, Ohio, and Missouri rivers - provides a unique aquatic habitat to which 30 kinds of Missouri fish have become adapted, 10 of which can be found nowhere in Missouri except in such slow, muddy waters. Some of these fish, including the silver lamprey, the paddlefish, and several kinds of gar and sturgeon, are very ancient species, leftovers from late in the Age of Dinosaurs when the Mississippi first became one of the world's principal centers of freshwater fish evolution. Others are more recently evolved and have grown accustomed to the silty flow during the intervening millennia.

The gar is an ancient species left over from late in the Age of Dinosaurs when the Mississippi first became one of the world's principal centers of freshwater fish evolution.



Excluded from these muddy, lowland rivers are more than 60 kinds of Missouri fish and amphibians living in upland tributaries of the Missouri and Mississippi, but which are never or are rarely ever found in the Big River System itself. Such a distribution pattern clearly illustrates the power of the Missouri-Ohio-Mississippi waterway in isolating aquatic species. For most

Jim Hawker

Before cars and bridges, the western, or ornate box turtle was mainly confined to the grasslands west of the Mississippi.

terrestrial plants and animals (those living on land), however, the wide, muddy waters of the big rivers have been relatively weak barriers whose ability to prevent dispersal, while varying from one species to the next, has never been an unbreachable wall. Although the Mississippi River and its broad flood plain seem to have delayed the eastward spread of the ornate or western box turtle, for example, and at the same time to have checked the westward expansion of the eastern box turtle, neither species has been absolutely excluded from the other's territory. Similarly, the American beech, American holly, and tuliptree may originally have been confined to the forests of the East, but they have since been able to cross the river and reach the wooded slopes of Arkansas and Missouri.

The Mississippi has generally only slowed the passage of plants or animals in their eastward or westward dispersions. For much of the prehistoric past, the river was neither wide enough nor swift enough to prevent the occasional drift of individuals back and forth. This is even truer today, when 8-year-olds routinely transport everything that slithers, crawls, swims, or flies from one state to another.

Nonetheless, the Big River System doesn't always interfere with plant and animal movements. At times, the Mississippi, Ohio, Missouri, and other rivers have been genuine thoroughfares - what biologists call **corridors of dispersion** - through ecologically hostile territory, providing routes by which creatures could gain entry into Missouri, or spread to other places. Because of its north-south orientation, the Mississippi has been especially important in the mixing of species between the Gulf Coast and the Great Lakes regions. The Ohio and Missouri, on the other hand, have assisted plant and animal travelers from the western prairies and the eastern forests.

In what may be the most bizarre example of such dispersion, the Mississippi provided a one-way express lane to St. Louis for an 84-pound bull shark. (That's right. We said shark!) A saltwater fish that has been implicated around the world in many attacks on humans, the bull shark is famous for its ability to ascend freshwater streams great distances. In this particular case (maybe there have been others?), the fish traveled nearly 1,800 river miles from the Gulf of Mexico, eventually reaching a point just above St. Louis. There, on September 8, 1937, it ran afoul of a fish trap, much to the dismay of the trap's very surprised owner, and became a strange footnote in biological history.

The "Father of Waters" has helped disperse other strange fish. In 1963, the plant-eating Asiatic grass carp was first introduced into experimental ponds in Alabama and Arkansas to see if it might be useful in controlling water weeds. During massive rains some of these exotic (foreign) fish were swept into tributaries of the Mississippi and spread quickly throughout much of the Big River system. They are now well-established in at least 34 states. A protective Missouri statute prohibiting the intentional release of the alien grass carp in the state became redundant overnight.

Jon Hawker

The Big Rivers of the continental center allow corridors of dispersion for plants and animals as they do for humans.

The river network has shifted naturally-occurring aquatic and semi-aquatic species with equal ease. Like the exotic grass carp, Gulf Coast animals such as alligator gar, anhinga (or water turkey), rice rat, and swamp rabbit also gained entry into the state along the Mississippi waterway. From the opposite direction, these great rivers have funnelled the northern pike, silver lamprey, spottail shiner, and burbot, along with a host of insects, mollusks, and other invertebrates.

North America's Big Rivers have served both as weak barriers and as powerful corridors of dispersion. The Mississippi, for instance, has tended to hold terrestrial creatures within a general western or eastern region. But the rivers have also allowed aquatic creatures that can survive in their waters to pass easily from one region to the next.

A Broader View

While Missouri's geographical position and climate determine what major North American biomes will be represented within its borders, other broader factors must be considered to explain the existence of those biomes in the first place. The geological events that created the Ozark uplift and the Big River System, providing isolated environments and corridors of dispersion, have contributed to Missouri's modern species diversity and its landscape in other equally significant ways. We must journey far back in time if we are to understand the modern landscape. The geological history of Missouri includes elements that have greatly influenced the biology of the state and the constitution of its natural communities. Powerful forces humans have only just begun to understand and measure have so altered conditions on this earth that only recently have their impacts on biology and evolution begun to be analyzed and appreciated. **Continental drift** is among the most powerful of these under-appreciated forces.

Simply put, the continents of our earth have been in nearly constant motion since they first formed in the earth's cooling crust. As a result, continental climates have changed and their surfaces have been altered. Obviously, continental movements - and their associated climatic and surface changes - are fundamental to describing the modern Missouri landscape and the creatures that now reside in the state.

The early colonists and explorers in North America ventured into a world that was new in many ways, but not totally alien. Biologically, much of North America resembled prehistoric Europe, before the most densely populated portions of that continent were tamed by centuries of agriculture and advancing technology. The plants and animals the settlers encountered on Virginia and Carolina shores were roughly equivalent to those they had left behind in familiar (albeit scattered and isolated) homeland settings. True enough, the New World habitats, while never actually wilderness, were certainly less disturbed, altered, and controlled. And it is also true that many species (and even whole groups of species) were unique to the Western Hemisphere and were not shared. Yet the plants and animals seemed familiar to the settlers because of their close relationships to species in the Old Country. So familiar, in fact, that many new but similar North American species were even christened with European names.

As familiar as the flora and fauna of the North American and European continents might have seemed, the native species of South America gave the impression of an alien world, one that was truly new. The first European explorers in South America wandered into a biological world that was totally foreign. There was little to remind them of home and the differences they saw could not be attributed entirely to the contrast of temperate and tropical climates. The closer biological relationships of North America and Europe (which are not in actual physical contact) and the striking differences between North and South America (which are connected) are, in large part, a direct result of continental drift.

How Does A Continent Move?

It is certainly not within the scope of this book to attempt a detailed explanation of the mechanisms of continental drift. For further information, curious readers are referred to other excellent sources on plate tectonics. Nonetheless, because the consequences of continental drift are significant to the creation of the modern Missouri landscape and to the composition of its flora and fauna, a brief description of this earth-altering process is in order. A simple chronology of the events associated with the movement of the crustal plates, as well as changes they wrought in the appearance and climates of the North American continent, is vital to understanding a number of geological and biological phenomena in Missouri.

First, we must understand that continental drifting is not the great cataclysmic, earth-rending event we might imagine. We hardly need hang on as if we were all loose and flying around the globe. The various continents and their parts drift away from each other at average relative speeds that range from the barely measurable up to several inches a year. In fact, until recently the rates of drift were too subtle for earthbound people to measure at all. Initially, the velocity of moving continents could only be determined by averaging intercontinental distances over incredibly long periods of time, often hundreds of millions of years. Now, in the Age of Space Travel, the actual rates of continental movements have become measurable with sophisticated satellite tracking devices and lasers.

While largely unseen, some of the shifts in continental positions do not pass undetected, especially by those living at the edge of a continental sheet. It is an unfortunate fact that most continents do not creep steadily at the speed assigned them by simply averaging times and distances. Instead, sudden movements of several feet or many yards, perhaps only once in each century or two, destroy whole cities and towns with their attendant earthquakes. This is what happens along the western coast of North America. At the eastern side of our continental plate the movements, while potentially as dangerous, seem to be more infrequent.

Even now, as you read this page, the North American continent subtly drifts away from Europe, driven by the upwelling of new molten material in the center of the Atlantic Ocean. Much like the water in a vessel held at a rolling boil (but infinitely slower), heated material from deep within the earth rises to the surface, spreads, then sinks to be reheated. From pole to pole, a high chain of volcanic peaks, called the mid-Atlantic Ridge, roughly bisects the Atlantic Ocean. The injection of molten rock along this ridge slowly separates the floating North American crustal plate from the European plate. Relative to America, Europe drifts off in the opposite direction.

There is almost constant volcanic activity at one point or another along this great tear in the earth's crust, and along a dozen similar rifts elsewhere around the globe. Over millions of years, this vulcanism has resulted in the formation of most of the mid-Atlantic's islands, including the Azores, Iceland, Tristan da Cunha, and Ascension. Whole chains of rugged peaks dot the Atlantic floor, although they are seldom high enough to break the ocean surface. While the eruptions of these volcanoes can hardly be called peaceful, most pass unwitnessed in isolation and therefore seldom have destructive effects like Mount St. Helens or California earthquakes.

As the immense mass of the North American plate drifts slowly westward, its shifting movements produce tremendous friction against the underlying layers of the earth and create many of the seismic effects that can be seen - and more often felt - at the surface, in California, and probably in Missouri as well. The worst effects occur where the North American Plate abuts the Pacific Plate pushing toward us from the west. The Sierra, Cascade, and Rocky Mountain chains are all visible products of this friction and collision. Their rocks simply folded up and buckled as a result of the irresistible pressure of the colliding continents, grinding and dragging along.

Some places on the earth show a continuing trend toward the division of the present continents into still smaller land masses. For instance, a long strip of our west coast, including Baja California, is slowly separating from North America and is traveling northward, taking Los Angeles with it. Much of this northward-drifting material has already piled up to form Alaska. On the other side of the world, the Great Rift Valley of Africa threatens to rip the Horn of Africa right off the head of the dark continent, leaving a new island of Ethiopia adrift north of an earlier wandering piece, Madagascar.

Closer to home, a long-hidden fracture, or rift, runs right through the Bootheel. Deeply buried beneath thousands of feet of rock and sediment, this weakness in the earth's crust began forming hundreds of million years ago. This is the source of the New Madrid earthquakes and the almost continuous seismic activity in the region. Some geologists have suggested that the constant westward drift of the North American plate squeezes this deep fracture together, preventing it from further rifting, and keeping the "lower 48" intact. It seems there is no such thing as a "solid earth."

Missouri's European Connection

Strong evidence indicates that early in the Triassic Period, roughly 200 to 225 million years ago (see the "Geological Time and Events" chart) only a single great continent existed on earth. There are indications that this huge land mass had itself only just formed from the aggregation of smaller continents, a hundred million years or so earlier. Unfortunately the disposition of these earlier continental masses is iffy; time and erosion have erased much of the evidence of the most ancient drifting patterns. Nevertheless, reconstructions show that this oldest recognizable supercontinent included all of our present continents, fused along their margins into a single massive continent called **Pangaea**.

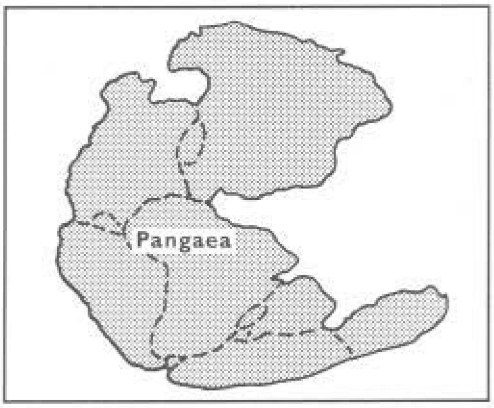
About 200 million years ago, Pangaea began to be ripped apart by the currents and tides of molten earth that constantly flow and swell beneath the none-too-solid crustal surface. At a rate so slow that it would not be noticeable even to many successive generations of humans (even had there been humans around at the time), this giant supercontinent was gradually torn into two slightly more recognizable land masses: a northern supercontinent called **Laurasia**, consisting of

Geological Time Scale for Missouri

ERA PERIOD EPOCH (or formation)	DATE (BEFORE PRESENT)	MAJOR EVENTS
CENOZOIC "recent life" (From the present to 65 million years ago)		
QUARTERNARY "the forth part" (From the present to 2 million years ago)		
HOLOCENE "whole recent"	Present to 10,000	Alluvium deposited in valleys; development of modern soils
PLEISTOCENE "most recent"	2 million to 10,000	Beginning and end of Ice Age.
	-12,000	Arrival of humans
Wisconsinan Glacial	55,000	Last ice advance; Mississippi cuts 100-200 feet deeper than at present, later refills with alluvium; final formation of Mississippi, Missouri, and Ohio rivers; modern surface of Ozarks completed by erosion and entrenchment
Sangamon Interglacial.		
Illinoian Glacial	375,000	Third ice advance over N. America.
Yarmouth Interglacial		
Kansan Glacial	1.2 million	Last glacial ice in northern Missouri; maximum extent of ice in state.
Aftonian Interglacial		
Nebraskan Glacial	1.5 million	First glacial ice in Missouri.
TERTIARY "the third part" (from 2 to 65 million years ago)		
PLIOCENE "more recent"	6 to 2 million	Isthmus of Panama established; exchange of species between N. America and S. America begins; exchange with Eurasia continues; uplift of Ozarks ends; entrenched meanders deepen; deposition of Lafayette Sands in Bootheel; first manlike apes evolve.
MIOCENE "less recent"	24 to 6 million	Last Ozark uplift; First cutting of present entrenched river channels. Camels evolve in North America.
OLIGOCENE "few recent"	36 to 24 million	Land connections established between Asia and N. America; last marine sediments deposited in Bootheel; first monkeys and apes.
EOCENE "dawn of recent"	58 to 36 million	Separation of N. America from Eurasia; Wilcox sands deposited in Bootheel; spread of mammals; first primates.
PALEOCENE "old recent"	65 to 58 million	End of separation of S. America and Africa; Midway sands deposited in Bootheel; spread of mammals; first primates.
		Second major uplift of the Ozarks; beginning of lower Mississippi.

ERA PERIOD EPOCH (or formation)	DATE (BEFORE PRESENT)	MAJOR EVENTS
PALEOZOIC (Continued)		
DEVONIAN "of Devonshire, England"	400 to 345 million	Ammonoids arise, trilobites radiate; first forests of fern allies; first amphibians; first bony fish and shark-like fish. Graptolites extinct.
Bushberg		
Glen Park		
Louisiana		
Grassy Creek		
Saverton		
Snyder Creek		
Fortune		
Callaway		
St. Laurent		
Beauvais		
Grand Tower		
Clear Creek		
Little Saline		
Bailey		
SILURIAN "of the Silures," ancient British tribe	430 to 400 million	Foraminiferans arise; first land plants (mosses and liverworts) and animals (millipedes, centipedes and arachnids); first fish with jaws.
Bainbridge		
Sexton Creek		
Bowling Green		
Bryant Knob		
ORDOVICIAN "of the Ordovicies," another British tribe	500 to 430 million	Missouri covered by seas; crinoids, ammonoids, brachiopods, graptolites all arise; first vertebrates - jawless armored fish.
Leamon		
Girardeau		
Thebes		
Maquoketa		
Cape		
Kimmswick		Underlying rocks of Lincoln Hills section, northern Jefferson Co., west St. Louis Co.
Decorah		
Plattin		
Joachim		
Dutchtown		
St. Peter		Source of glass at Crystal City
Everton		
Smithville		
Powell		
Cotter		
Jefferson City		
Roubidoux		Red sandstone along I-44 at Rolla. Massive dolomite of upper portions of Meramec River bluffs.
Gasconade		
Gunter		

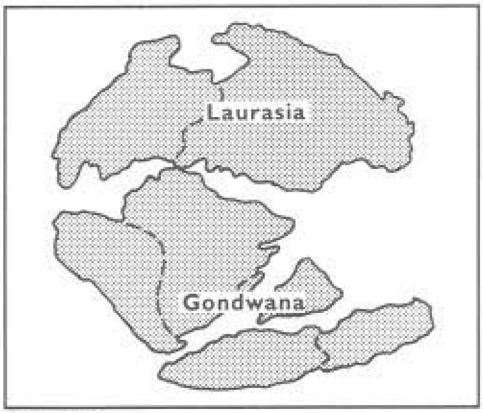
MESOZOIC "middle life" (from 65 to 225 million years ago)		
CRETACEOUS "chalky"	135 to 65 million	Beginning of breakup of Gondwanaland into S. America and Africa; Mississippi embayment is formed as a depression, then oldest marine sediments laid down, later to become Crowley's Ridge; rise of flowering plants; rise of bony fishes; end of the dinosaurs, ammonoids and brachiopods.
JURASSIC "of the Jura Mountains"	190 to 135 million	End of separation of Pangaea; first birds; first flowering plants; ferns and conifers peak.
TRIASSIC "third"	225 TO 190 million	Beginning of separation of Pangaea into Gondwanaland and Laurasia; Ozarks leveled by erosion and covered by seas several times; first mammals, first dinosaurs; dominance of ferns and conifers; decline of amphibians.
PALEOZOIC "old life" (from 225 to 570 million years ago)		
PERMIAN "of Perm Province, Russia"	280 to 225 million	End of formation of Appalachian Mountains; Ozark uplift 3-4,000 feet as part of that process. First mammal-like reptiles; rise of conifers; decline of foraminiferans; end of crinoids and trilobites.
CARBONIFEROUS "coal-bearing"	350 to 280 million	
PENNSYLVANIAN "of Penn."	310 to 280 million	Club moss and horsetail forests; formation of coal deposits; amphibians dominant; first insects and reptiles; ancient fishes extinct. Sandstone glades - western Missouri.
Channel Sands		
MISSISSIPPIAN "of Miss."	345 to 310 million	Rise of amphibians; crinoids, foraminiferans radiate; nautiloids extinct.
St. Louis Salem Warsaw Keokuk Burlington Elsey Reeds Spring Pierson Fern Glen Chouteau Northview Sedalia Hannibal Compton Bachelor		
PALEOZOIC (Continued)		
CAMBRIAN "of Wales"	570 to 500 million	First trilobites and corals; many ancient groups established; many soft-bodied forms become extinct.
Eminence		Dolomite of large Ozark river bluffs; principal Missouri cave and spring forming stratum; much chert.
Potosi		Dolomite, drusy quartz, and chert; Washington County barite and lead deposits.
Derby-Doerun Davis		
Bonneterre		Oldest dolomites in Missouri; many fossils; old lead belt deposits at Bonneterre and Flat River.
Lamotte		Oldest major sedimentary rock-results from first major erosional phase in the Ozarks; Missouri covered by seas; first shelled animals; few fossils - brachiopods; formation seen at Hawn State Park.
PRECAMBRIAN "before Cambrian"	(4,500+ to 570 million)	
	1,150- to 900 million	Second phase of first uplift of Ozarks, first erosional phase from now until upper Cambrian - Lamotte; first green algae, jellyfish, and segmented worms.
	1,400 to 1,200 million	Intrusion of granites in rhyolites (Elephant Rocks). First phase of first principal uplift of Ozarks.
	1,600 to 1,400 million	Heavy volcanic activity, formation of Ozark rhyolites; oldest Missouri sedimentary rocks from oldest weathered igneous rocks, uplifted by first Ozark uplift; oldest fossils in Missouri, blue-green algal stromatolites left behind on surface after first Ozark uplift. Green algae arise.
	3,500 million	First life on earth; bacteria and blue-green algae evolve.
	4,500 million+	Formation of the earth.



220 million years ago.

Europe and North America, and a southern **Gondwana** supercontinent, composed of South America, Africa, India, Antarctica, Australia, and New Zealand.

As the northward-drifting Laurasia began to actually separate from Gondwana in the late Triassic and early Jurassic, flowering plants were as yet unknown. Birds were just beginning to flit through the branches of ancient kinds of conifers and other primeval plants, now long extinct. Only the smallest, most primitive kinds of mammals crept among the dark forests, hiding from a growing array of formidable dinosaurs. By the end of the Jurassic Period, at the peak of the reign of dinosaurs, the separation of the two supercontinents was complete.

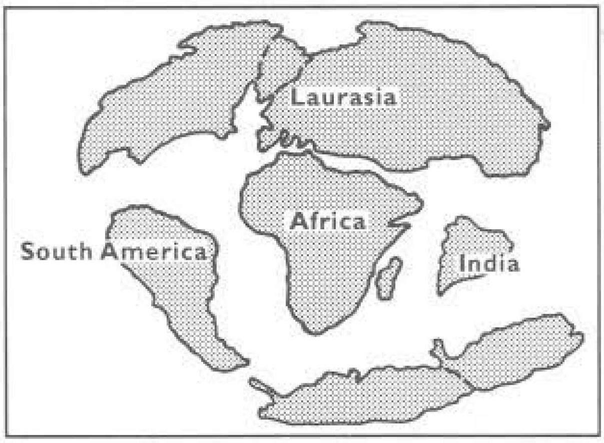


180 million years ago

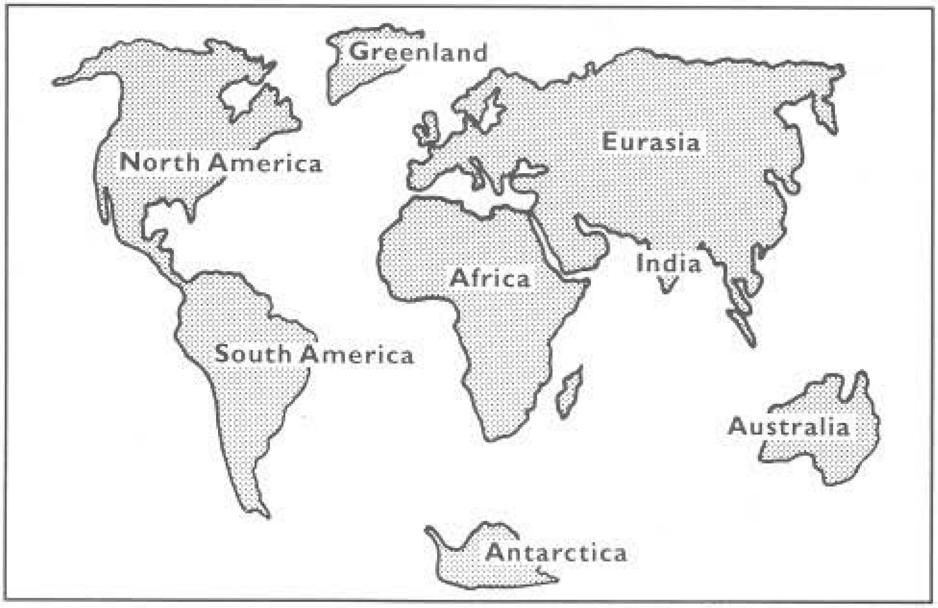
The isolation of the primitive plant and animal populations on the two new continental masses allowed evolution to proceed independently on each for tens of millions of years with only the basic blueprints of more advanced life forms to work with. In response to the different sets of living conditions now available on each separate land mass, the evolutionary track followed by their isolated species gradually yielded two very different groups of organisms. Toward the end of this initial period of drifting, the still-primitive floras and faunas of Laurasia and Gondwana had already become quite distinctive. Even today, many of these early differences remain between the plants and animals of the northern and southern hemispheres.

The unsettled Gondwana supercontinent existed only briefly, in geological terms, before it, too, was separated into its modern daughter continents, subcontinents, and islands. The major part of this tedious process, lasting more than 100 million years, began in the Cretaceous. It was at the end of this period that the dinosaurs mysteriously relinquished their hold on the earth, and the mammals and birds took over. The fracturing of Gondwana finally ended only 50 or 60 million years ago, about the time that primitive primates were just gaining a secure foothold on the planet.

65 million years ago



Laurasia, the northern supercontinent, seems to have succumbed to the inexorable forces within the earth a bit more reluctantly. Many modern plant and animal families were already well established throughout Laurasia by the time it finally began splitting apart, a rending that commenced millions of years after the southern continents were already near their modern positions. Because the separation



Present

of Laurasia and its ancient plant and animal groups was more recent, the North American and Eurasian descendants of these common ancestors are more similar to each other than they are to any of the plants and animals that evolved independently in the southern hemisphere. A brief glance at the flora and fauna of the southern continents - such as southern beeches, podocarps, and proteas - shows that they, too, are as much related to one another as they are unrelated to the plants and animals of the northern hemisphere.

Millions of years of isolation have since forced each North American and Eurasian descendant to adapt independently to its own local environment. As a result, mirror-image reproductions may not always occur on the two northern continents. For instance, members of the magnolia, willow, oak and beech, lizard's-tail (a unique plant of Missouri's wet areas), and other old flowering plant families are found on both continents of the Northern Hemisphere, but separate and distinct species characterize each. Poisonous vipers are common to both North America and Eurasia, but only the American branch developed heat-sensitive pits and a subgroup whose members sported rattles. Sometimes an entirely new family appeared. The sturgeon and paddlefish families are both ancient and shared by North America and Eurasia, but the more modern sunfish family evolved independently only in the Western Hemisphere. The mammals, most of which evolved since the great split, originally showed the greatest differences, and the continents would maintain these differences for millions of years. However, continuing geological events would ultimately intervene to shuffle North American and Eurasian mammals together.

Because the Laurasian supercontinent remained intact long after it had separated from Gondwana, the blueprints of life shared by each of its future subcontinents, North America and Eurasia, would eventually result in the sharing of very similar groups of organisms by the two northern continents. In fact, it makes far better sense, biologically, to distinguish between "Southern" and "Northern" worlds, than between our familiar, historical "New" and "Old" worlds, or between "East" and "West."

Members of the lizard-tail family are found in North America and Eurasia.

Jon Hawker

South American Distinctions

Not until late in the Miocene or early in the Pliocene epochs of the Tertiary Period, roughly 7 or 8 million years ago, long after the division of Laurasia into North America and Eurasia, were North and South America finally brought together. By this time, two entirely different sets of plants and animals had evolved on the two continents. North American mammals, for instance, were all placentals, that is their embryos were carried to birth size internally and nurtured by the mother's blood supply through an afterbirth, or placenta. A large proportion of South American mammals, on the other hand, utilized a more primitive reproductive style in which the young are born after only a few weeks of development, then carried to "birth size" in a pouch and fed milk. The pouch is called a marsupium and the animals that carry them are known as **marsupials**. Along with their primitive reproductive features, marsupials are also distinguished by lower body temperatures and rather small, primitive brains with undistinguished mental capacities, a trait that is sometimes only too obvious in Missouri's only marsupial, the opossum.

Although the gradual union of the continents provided a narrow corridor across which mixing of long-isolated northern and southern species could occur, it was not equally accessible to all. While the Middle American land bridge has now been available for millions of years, many plants and animals have never made the passage. For some reason the thin strip of land we know as Central America seems to have filtered the species dispersing in one direction or the other.

The reasons are probably varied, but it is likely that most freshwater or land animals simply could not survive the arduous journey through jungle and desert, over mountain, and across swamp to reach the other continent. There are far too many different kinds of barriers. Of course, vegetation would be similarly limited by the need for particular soils and moisture amounts; thus, sensitive species would be "filtered out" by the land bridge. Even if plants and animals were able to overcome the many physical and climatic barriers thrown in their paths, some may have been held back by fierce competition with similar groups of organisms already well entrenched on the other continent.

The South American family of cichlid fish, which includes such familiar aquarium species as the discus, Jack Dempsey, and Oscar, evidently attempted the northward migration some time back. Thus far, however, they seem to have been held at bay in northern Mexico by the ecologically similar and equally aggressive members of the North American sunfish family. Despite such competition and the physical barriers erected by the Central American land bridge, South America has still managed to squeeze a few of its own into the floral and faunal mix of North America, and Missouri.

The ordinary and unspecialized opossum, for instance, having wandered north across the new Isthmus of Panama late in the Pliocene, was one species that would achieve unparalleled success. The opossum has been the only marsupial in all of North America for over a million years. The 'possum's high reproductive rate, its relative tolerance of cold, and its generalized diet have all contributed to its remarkable prosperity in North America, despite apparent attempts to pave our highways with fur. In a sense, the sluggish, dim-witted opossum brought the history of marsupials in the New World full circle, since its family first evolved in the North American part of Pangaea, spread into the South America portion, then died out back in Laurasia as modern mammals arose. When the South American 'possum came north, it left behind a family of 60 relatives, most of whom still hold out against the inroads of incoming North American species.

Ancestors of our familiar opossum wandered into North America from South America several million years ago.

Jon Hawker

Among the gringos to migrate south over the new Central American connection was an ancestor of the long-nosed and ring-tailed coatimundi, an exceptionally versatile member of the raccoon family. The forerunners of the coati passed into South America at about the same time the opossum came north. Many other northern placental mammals followed. With their larger brains, higher activity levels, and more advanced reproduction they quickly overran the lowly marsupials of the southern continent.

In the meantime, other South American mammals availed themselves of the Central American land bridge, including the porcupines. However, the most unusual Latinos to come north were the Edentates. The name implies that this group - the armadillos, sloths, and anteaters - are toothless. In reality, most Edentates have small, peg-like teeth. Unlike the South American marsupials, which generally became extinct shortly after the invasion of the coati and other North American placental mammals, some families of edentates seem to have easily withstood the competition, at least in the beginning. Many Edentates actually became quite common in North America during the Pleistocene Epoch, the Ice Ages, although none would achieve the same pinnacle of success, nor hold it so long as the lowly 'possum.

Harlan's ground sloth, for example, a direct descendant of the first of its family to migrate from South America, quickly became a dominant member of our early Ice Age communities. Modern sloths are all smallish, proverbially lethargic, and hang upside down while nibbling leaves. Had prehistoric ground sloths tried anything so reckless they would have crashed to the ground still clinging to the torn limbs. Up to 20 feet long, the giant Harlan's sloth was not only the largest (perhaps 2 or 3 tons!) but also the most widespread edentate during the first period between glaciers (the Aftonian Interglacial). After an impressive North American reign of a million years or so, however, it was replaced by a more adaptable relative, the Jefferson's ground sloth.

Smaller than its ancestor, Jefferson's ground sloth was a hairy beast only 5 feet high at the shoulder when crawling on all fours, but still capable of reaching 12 feet when standing on its haunches. Like its truly giant relative, however, Jefferson's ground sloth was still a placid browser. Both species walked on the sides of their feet as they moved clumsily through the forest, pulling branches within reach with powerful front legs armed with gigantic claws. The most widespread and frequently encountered of the fossil sloths, Jefferson's was named in honor of its discoverer, Thomas Jefferson.

At first, Jefferson believed he had stumbled on the remains of a carnivore three times the size of a lion, owing to the sloth's impressive claws. As a devout fundamentalist, the great statesman had difficulty accepting that God would allow any species to disappear from the earth, and believed that the giant cat must still stalk the wilderness somewhere near at hand. Although a brilliant philosopher and architect, Jefferson was neither a particularly adept naturalist, nor much of an anatomist.

A colleague, also fortunately a close friend, pointed out that the giant claw actually belonged to a sloth, and a long extinct one at that. Although Jefferson's ground sloth had survived in North America for more than 250,000 years, it too ultimately failed to meet the demands of its rapidly changing Ice Age environment. Now entirely extinct everywhere, the remains of giant sloths turn up all across the country, although exceptionally well-preserved bones, hides, dung, and peculiar foot-long tracks are notable among the fossil remains of dry caves in the desert southwest.

The only other successful South American edentate immigrants were the armadillos. These "shelled" mammals diversified into a huge number of species in South America during the Ice Ages; one was as large as a rhinoceros. However, only a few of the smaller types - like the armored glyptodonts (a mere 4-footer) and other extinct species the size of our more familiar nine-banded armadillo - waddled north across the Middle American land bridge.

The remains of North America's few giant glyptodont species have been found in Florida, Texas, Oklahoma, Kansas, and, in our home state, in a pit cave in Jefferson County. These animals looked like nothing alive today, resembling a tailed VW bug more than anything else. Weighing a ton or more, the body was encased in an almost inflexible 6-foot "shell" of 2,000 or so fused plates. The head and tail were similarly armored and might have extended the animal's length to 10 feet. Inoffensive and tiny-brained plant-eaters, these living tanks wandered the moist habitats of southern flood plains on elephant-like limbs and probably nosed through the brush with a short, elephant-like proboscis as well. Most fossil finds of this creature are isolated limb bones and scattered bits of "shell," which evidently was too poorly fused to be fossilized intact. Consequently our conclusions about its lifestyle and habits must remain purely conjectural.

With 20 relatives still living south of the border, the nine-banded armadillo is probably familiar to all who have traveled the highways of the Gulf Coast. There is nothing conjectural about this armadillo's lifestyle or habits; its leathery shells litter the shoulders like discarded beer cans. Despite this evidence to the contrary, the armadillo is an adaptable survivor, like the opossum. Although it was not actually observed in the United States until it mysteriously began appearing in Texas in the 1850's, fossils in Texas caves prove its presence at least 3,000 years ago. Following its most recent appearance, the spunky, nearly toothless animal quickly expanded its range all across the south.

Members of the North American phlox family, which includes the Sweet William, migrated into South America.

Jon Hawker

A separate southeastern population, accidentally introduced into Florida, has spread along the east coast with the same ease. A cult of armadillo worship seems to have spread with the animal, giving rise to an array of armadillo icons in the form of belt buckles, stuffed specimens, and other strange paraphernalia.

While the nine-banded armadillo was occasionally seen in southwestern Missouri during the 1960's and early 1970's, spawning rumors of an armadillo invasion, the armored mammal now seems generally confined to coastal states. The animal may simply prefer the sandier soils of the South, or perhaps extreme temperatures or shortages of insect food during our midwestern winters restrict permanent settlement this far north. If so, individual armadillos may waddle into the state from time to time, as they did in an area south of Springfield during the relative warmth of the late 1980's and early 90's, then waddle back out again as more severe winter temperatures returned.

Other kinds of animals have been less or more restricted in their travels by virtue of their body plans. Many of our birds and even some flying insects - the monarch butterfly for instance - still routinely make all or some part of the trip from

North America to South America simply as a function of the changing seasons. The common snapping turtle, as rugged and persistent as any animal on earth, and an inveterate wanderer to boot, has made it at least as far south as Ecuador. Other less mobile species, like mollusks, crustaceans, fish, frogs, and salamanders, (without human help) are likely to remain trapped forever on the continent where they evolved.

The story of intercontinental dispersion is not as clear among plants because the fossil record is scanty or non-existent. However, a number of Missouri's smaller plant families - those with only one or two members currently living in the state, but with a large number of relatives in South America - may have taken advantage of the northern route alongside the sloths, 'possums, and armadillos. Trees such as the familiar persimmon, pawpaw, and mulberry, and vines, like the passion flower and moonseed, are likely candidates for this northward list, as are the less familiar Missouri acacias and mimosas, members of the pea family. A few North American plant groups native to Missouri clearly show the reverse migration pattern. Among these are the dogwood, horsechestnut, bladdernut, cattail, and phlox families, which have managed to gain footholds in Latin America.

The basic distinction between the northern and southern hemispheres established by the early drifting of the continents has remained millions of years after their physical separation. Some species have been able to bridge the gap between North and South America; most have not. Although the South American connection shows up occasionally in Missouri's plant and animal mix, the climatic differences between the two continents restricts the number of species that can make the jump. For example, only three species of mammals originating in South America have persisted in North America to the present day without human help: the opossum, the armadillo, and the porcupine. Of these, only the opossum can be considered a resident of Missouri.

Continental drift set the stage for the isolation, evolution, and mixing of whole groups of species around the earth and is responsible for many of the natural phenomena we see on our planet. Because the present continental configuration has existed for millions of years, many of the earliest biological implications of drift have been masked by more recent geological events.

Even hundreds of millions of years before the geological record begins its tale of drift, however, other colossal changes were taking place on the face of the North American continent as it wandered about. In terms of Missouri landscapes the most significant was the creation of the Ozarks. Again, as is true of the earliest stages of continental drift, the picture of the first millennia of the Ozarks has been obscured by time, erosion, and the formation of new rock layers. Nevertheless, sufficient material exists for geologists to have pieced together a fairly complete story.

The Appearance Of The Ozarks

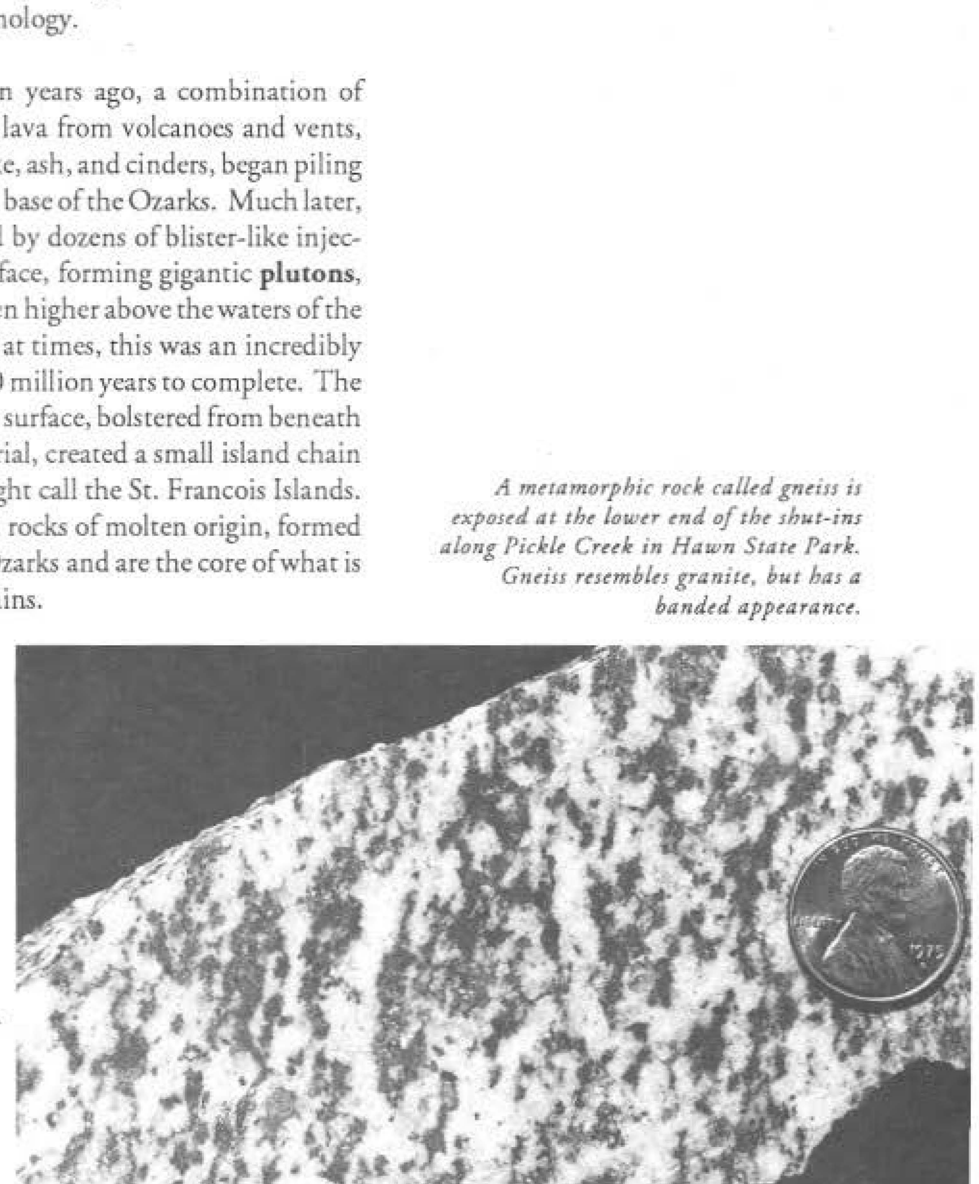
Most accounts of the origin of the Ozarks begin between 1.65 and 1 billion years ago, during the latter part of an immense span of time widely known as the **Precambrian Era** or Eon. Early geologists defined the duration of the Precambrian as that long period between the formation of the earth and the evolution of life. None of the hard rocks of such great age known to 19th century geologists preserved any recognizable fossils, so they were forced to conclude that all life had begun at some later time. The oldest distinct fossils they had been able to locate and date were from rocks in Wales, a region called Cambria by the Romans, whose rocks then became the standard for defining the Cambrian Period. Anything older than the **Cambrian Period**, beginning roughly 600 million years ago, was then referred to as Precambrian.

Today, from fossils collected in places inaccessible or unknown to the geologists of 150 years ago, it is recognized that life began almost three billion years earlier than the Cambrian. Although scant, the evidence is conclusive and includes the well-preserved impressions of soft-bodied marine creatures in fine-grained Australian and Canadian rocks, and microscopic fossils from a number of locations going back 3.5 billion years and more.

The great age of these findings, and the immense span of time they encompass, has forced geologists in recent years to make some changes in the naming of geological time categories and in the definition of Precambrian. Terms such as Archean, Priscoan, Hadean, Proterozoic, and others have been applied to various-sized portions of the 4 billion years of Precambrian time. As yet, however, no universal agreement among geologists has been reached as to which of these will remain in official usage and to what period of time each might be applied. For this reason, and because Missouri's rock record seems to offer evidence of only the most recent billion years or so of the Precambrian, we will use only that term in the text. However, the geological time chart offers one possible arrangement of the Precambrian using some of the newer terminology.

In any case, at least 1.4 billion years ago, a combination of hundreds of separate outpourings of lava from volcanoes and vents, accompanied by blasts of steam, smoke, ash, and cinders, began piling debris that would eventually form the base of the Ozarks. Much later, these violent eruptions were followed by dozens of blister-like injections of molten rock beneath the surface, forming gigantic **plutons**, that pushed the first Ozark surface even higher above the waters of the ancient ocean. Although cataclysmic at times, this was an incredibly slow process, requiring more than 500 million years to complete. The extrusions of lava that spilled onto the surface, bolstered from beneath by intrusions of unseen molten material, created a small island chain in the primordial ocean, what we might call the St. Francois Islands. These ancient **igneous rocks**, that is, rocks of molten origin, formed the foundation layer of the modern Ozarks and are the core of what is today called the St. Francois Mountains.

A metamorphic rock called gneiss is exposed at the lower end of the shut-ins along Pickle Creek in Hawn State Park. Gneiss resembles granite, but has a banded appearance.



Art Hebrank

The heat and pressure generated by this enormous volume of new rock remelted and recrystallized the older rocks lying beneath, rocks whose age is probably twice that of the oldest Ozark rocks. The reforming process, called **metamorphism**, gradually produced a broad footing of extremely hard metamorphic rock under the Ozarks. Erosion in Missouri has exposed very little of this altered type of rock, although one kind, called **gneiss**, was created when an older granite was remelted during a period of intrusion. This attractive metamorphic rock may be seen in an exposure at the lower end of the shut-ins along Pickle Creek in Hawn State Park.

Jon Hawker

Some days the rhyolites are barely visible at Johnson's Shut-Ins State Park

Exposed to seawater, or wind and rain, the first lavas extruded on the St. Francois surface cooled quickly, "freezing" the rock mixture in place, and allowing little time for individual minerals to separate into distinct crystals. These fine-grained, extrusive igneous rocks are generally called **rhyolites** or **felsites**. Rhyolites and felsites of variable colors, from purplish and reddish, to brown and black, and various crystal sizes, are exposed in many places in the St. Francois Mountains. Beautiful outcrops and exposures may be seen at many public sites, including Johnson's Shut-Ins and Sam A. Baker State Parks. Unlike granite, these massive rocks are brittle and not easily worked, and therefore find little polished, ornamental use. However, tons of this Missouri "trap rock" are crushed and used for paving, landscaping, and roofing shingles.

The younger intrusives, those later injections of molten rock, buried by hundreds and even thousands of feet of hardened lavas overhead, were well-insulated and cooled very slowly. Over many decades, centuries, and millennia, their various minerals were able to separate from one another and grow into large, distinctive crystals. Because of their bright colors, gem-like crystals, and ability to take a beautiful polish, these coarse-grained, intrusive igneous rocks, or **granites**, have found frequent use as headstones, paving and curbing stones, and building fronts. The most famous Missouri granite ("Missouri red") was cut and blasted from quarries in the vicinity of Elephant Rocks State Park at Graniteville.

Later, a third type of igneous rock literally shouldered its way among the rhyolites and granites, already in place for millions of years. Episodes of pressure and intrusion pumped this molten material into small fissures lacing the older rocks, expanding the cracks as they went, and forcing them up and outward. This material, from sources deeper within the earth, was of a totally different chemical composition than the older acidic rocks. These younger rocks are known as **basalts**, and they presumably represent the dense material from beneath the lighter, floating granites of the North American continental sheet.

The basalt solidified very quickly when it came in contact with the old, cold granites and rhyolites, forever preserving its smooth, almost liquid-like texture. The dense, homogeneous material is easily recognized today as distinctive black stripes that zig-zag through the more colorful igneous rocks surrounding them. Individual bands of basalt, called **dikes**, may be more than 24 inches wide as they snake through the older rocks, although they often taper quickly to narrow, jagged streaks, like cartoon-version lightning bolts. Small traces of this black rock creep through the roadcuts of U.S. 67 south of Farmington, while a much broader band slices down to the St. Francis River just below the old dam at Silver Mines near Fredericktown.

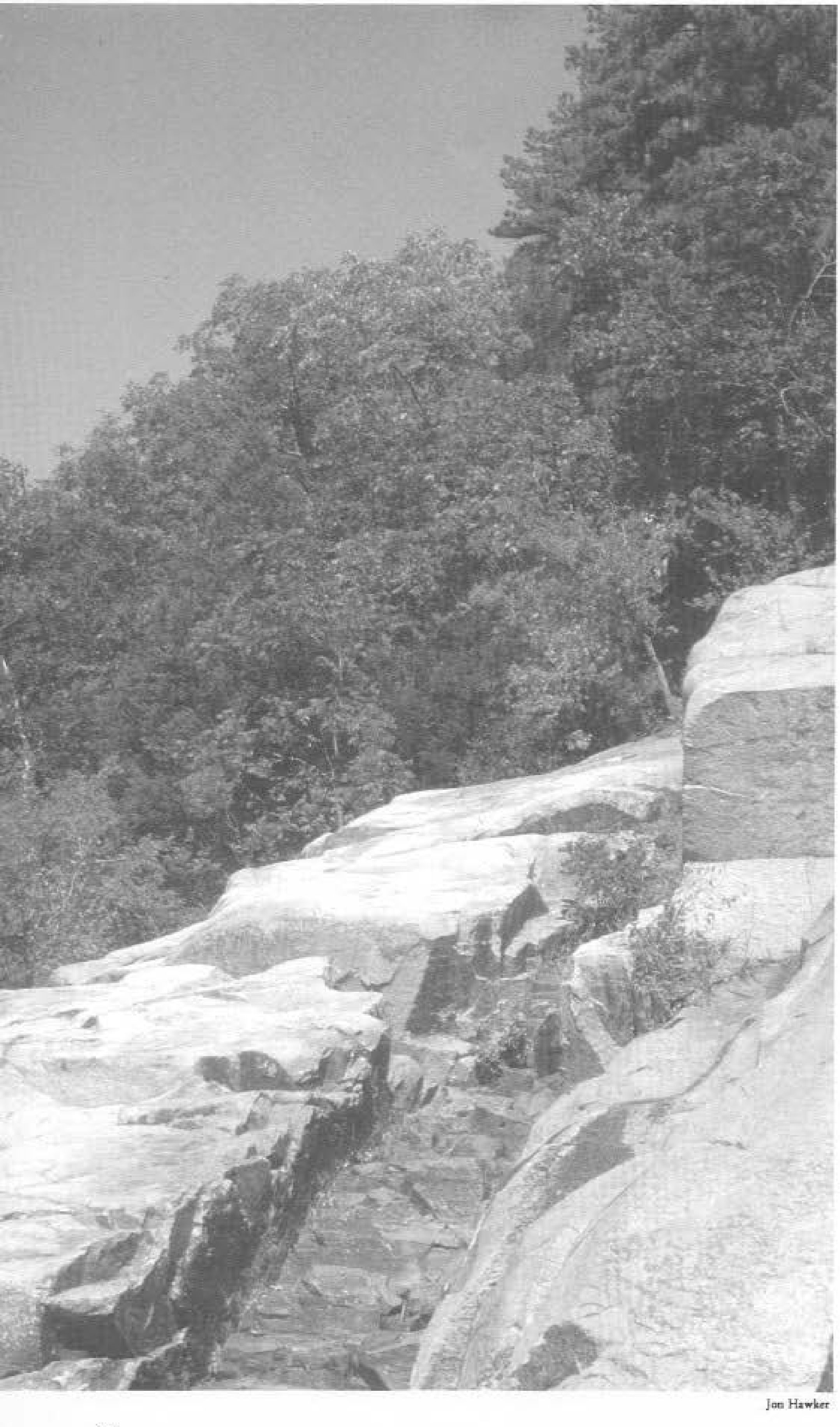
Several hundred million years of these earthly convulsions were necessary to create the deep layer of igneous rocks on which the rest of the Ozark structure would eventually be built. During these many millions of years of activity, thousands of feet of granites and rhyolites were pumped into the growing island chain. The accumulation of molten extrusive rocks at the surface, pumped up by the pressure of the younger intrusives beneath, eventually produced mountains that may have loomed as much as 10,000 feet above the ocean floor, although they probably reached no more than a mile or so above the surface of the water.

"Missouri Red" granite, quarried near Graniteville, has been used in rough-cut blocks as a local building stone, but when cut and polished, it is far more attractive for architectural uses.

ICE PLANT
ICE

Jerry D. Vineyard

Although the mechanisms of drift were undoubtedly active at this time, shoving the early continental plates this way and that around the globe,



A basalt dike slices through granite at Silver Mines.

Jon Hawker

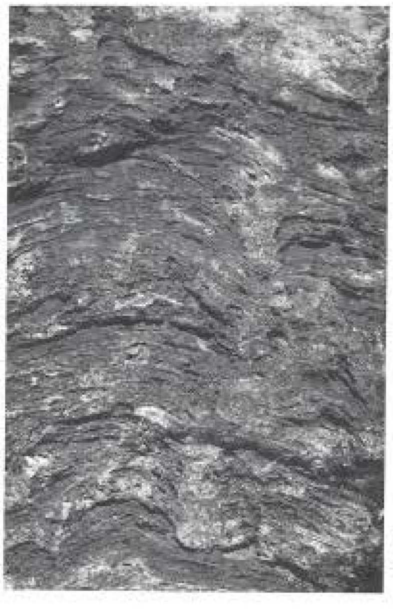
the supercontinent Pangaea had not yet been assembled. The formation of that great land mass was still hundreds of millions of years in the future. Nevertheless, continental drift was already having an impact on the development of plant and animal communities in the pre-Ozark seas, and would eventually influence the biology of the St. Francois island chain as well.

At the time, the crustal plate of the earth that would one day support our North American continent - for which some geologists have proposed the name Rodinia (from the Russian for "to grow" or "to beget") - was rotated 90° clockwise from its present position. The region that would become California was thousands of miles north, in the temperate zone, while imbedded deep within the center of this early supercontinent the area that was destined to become Missouri was positioned at or very near the equator. The early St. Francois Island chain arose to become balmy desert isles, much like the Galapagos or Hawaiian Islands of today, but with no animals and perhaps only just the slightest hint of green to soften their barren expanses of naked rock.

Missouri's First Settlers

The very simplest life forms, limited primarily to bacteria and other simple-celled creatures, were just beginning to diversify when all this rock began to be spewed onto the surface of the North American crustal plate. Even as the Ozark mountains slowly arose out of the sea, mushroom-shaped pedestals and smooth, curving reefs were being laid down along its shoreline by massive growths of billions of slimy, calcium-secreting bacteria. Such bacterial structures are called **stromatolites.** Modern stromatolites grow in an almost tree-like manner, with new concentric layers (seen in sliced specimens as "growth rings") being laid down on the outer surface. As each new layer of bacteria spreads across the surface of the older colony beneath it, it secretes a layer of minerals like a thin layer of veneer, sometimes augmented by sediment in the water that adheres to the sticky bacteria. Gradually this new band encrusts the older one, only to be choked off itself by another newer layer to the outside.

A Missouri fossil stromatolite shows a structure built layer by layer by generations of cyanobacteria.



Jon Hawker

Similar limy deposits are being secreted by bacteria in the sheltered coves of western Australia, the salty, desert lakes of Nevada, and the hot springs of Yellowstone National Park. Because they are all microscopic, photosynthetic organisms of a distinctive dark blue-green color, they were once widely referred to as blue-green algae. However, they are now more commonly known as the **Cyanobacteria** (cyan = dark blue). Cyanobacteria may be familiar to you as the slimy, blackish-green scums coating the rocks in your goldfish aquarium or creeping across the bottom of your dog's unwashed water bowl.

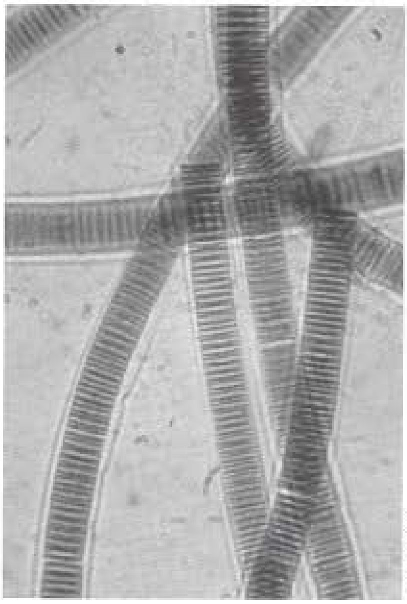
In the Precambrian, cyanobacterial colonies clung tenaciously to the shallow sea floor in quiet lagoons and backwaters, often where they were lapped by gentle waves. Others inhabited puddles on shore or gathered where superheated springwater issued from rocks just barely beginning to cool. The blue-green bacteria might not have been the only living things in the seas surrounding the new islands, but their remains are certainly the only ones evident today. While it is likely that some type of complex, soft-bodied creatures existed by the end of this period of Ozark vulcanism - perhaps wormlike or jellyfish-like in structure - their remains have not been found in any Ozark rocks. The only evidence of Precambrian life in the Ozarks remains frozen in time, interbedded with thin layers of volcanic ash and lava at such places as Cuthbertson Mountain (south of Arcadia in Iron County), where masses of blue-green bacteria blossomed in quiet pools around the St. Francois Islands some 1.4 - 1.5 billion years ago. Even older stromatolites have been found in other parts of the globe, a few dating back more than 3.5 billion years. In some Ozark localities, younger fossil "stroms" (as they are called by those in the know) form a considerable portion of the thick layer of sedimentary rocks that surrounds the igneous core of the highland, and may occasionally be seen in bluffs along Ozark creeks or rivers.

A Changing Earth - A Changing Atmosphere

While the reef-building role of blue-green bacteria along the world's oldest coastlines was certainly significant, the slimy algae-impersonators had another even more important effect on their environment. It is likely that the photosynthetic activities of these earliest chlorophyll-containing cells were responsible for the development of earth's first oxygen atmosphere. For nearly half of the 4 billion years of the Precambrian the planet was shrouded in an unlivable miasma consisting of some mixture of ammonia, nitrogen, carbon dioxide, carbon monoxide, hydrogen, water vapor, methane, sulfur dioxide, and/or hydrogen sulfide. The precise components and proportions can as yet only be guessed at. Nevertheless, we do know that oxygen was almost entirely absent. Virtually all oxygen on the earth remained chemically bound to other elements and was unavailable in free gaseous form.

Very few of our modern organisms could have survived in this noxious atmosphere. Only organisms capable of carrying on their living reactions without oxygen, those that we call **anaerobes** (= "life without air"), could thrive anywhere on earth. A few of these earliest kinds of anaerobic bacteria, called **Archaebacteria** (archae = ancient), survive today in concentrated salt brines, organic-rich acid bogs, acid mine seeps, hot acid springs near active volcanoes, and around "black smokers" (the deep-ocean, hot-water vents only recently discovered and visited by scientists), all places that are virtually free of oxygen. Almost all remaining species of bacteria, and higher forms of life, require oxygen.

The only source of free oxygen efficient enough to produce the modern earth's atmosphere (which holds very near 21% oxygen) is the combined result of the various processes of **photosynthesis**, whether by plants, algae, or bacteria. These remarkable reactions also produce the food eaten by almost every non-photosynthetic living being, whether amoeba, mold, snail, or human. Without photosynthesis there is no free oxygen and there is no free lunch. It is for this reason that we are today concerned more than ever with the uncontrolled cutting and burning of the world's forests, among our most important oxygen sources.


Jon Hawker

Simple photosynthetic bacteria such as these were responsible for the production of today's oxygen atmosphere. (Multiplication factor 1000x.)

Photosynthesis began with bacteria. Through light-absorbing processes almost identical to photosynthesis in modern plants, these primitive cells released oxygen in minute quantities for hundreds of millions of years, gradually transforming the ancient, noxious atmosphere of the earth (whatever its original components) into a breathable mixture dominated by oxygen and nitrogen. The process was slow because free oxygen is extremely reactive and was absorbed by various metals and other materials for tens of millions of years. The appearance of other modern forms of life must have followed long after the rise of the blue-green bacteria. Only when oxygen-absorbing reactions had nearly ceased and the chemical demands of the earth itself had been mostly satisfied could the atmosphere begin to build appreciable amounts of oxygen; only then could oxygen-breathing organisms begin to occupy the planet in numbers.

Blobs of photosynthetic blue-green bacteria still live in Missouri's freshwaters.

Jon Hawker

The atmospheric changes wrought by the rise of oxygen levels from photosynthesis are reflected in the rocks that were formed from freshwater and ocean sediments of the period. These rocks - some of which are called **red beds**; others are termed **banded iron formations**, depending on their characteristics and the site of their formation - contain significant amounts of reddish iron oxides. These rusty ingredients formed when less brilliantly colored iron compounds in water combined with newly released oxygen, then settled out and formed the rust-colored deposits. Most red beds and banded iron formations were formed between 1 and 3 billion years ago, indicating that the atmospheric change began quite early in the Precambrian and had largely been completed by the time Missouri's oldest surviving rocks were pushing above the ocean. Neither of these rock types has been found in Missouri. Elsewhere, however, these and other rusty sedimentary rocks laid down at this time - such as those in Minnesota, Labrador, Brazil, Venezuela, Australia, Africa, and Russia - provide our greatest sources of usable iron ore.

The change in atmosphere generated by the activities of the cyanobacteria also brought about the extinction of nearly all earlier forms of life to which free oxygen would have been as poisonous as cyanide is to us. Only in those unique, oxygen-free habitats already mentioned (hot springs, mine seeps, etc.), and some other places closer to home, such as on your teeth, have these earliest anaerobic types of bacteria survived. Some of our worst **pathogens** (= "disease-causing") are anaerobic bacteria, which is why hydrogen peroxide can be an effective antiseptic; its frothy bubbles are pure oxygen and pure poison (to them).

The Cataclysmic Surface

During the same period that our atmosphere was being formed and modified, the world's first oceans were also accumulating and changing. At first, the early earth was far too hot for water to condense and collect. Geological and astronomical studies of the moon and other bodies orbiting the sun tell us that the solar system began coalescing from a spinning cloud of dust and gases some 4.6 billion years ago, and that the earth and other planetary bodies were assembled into rough form during the next 100 million years or so. A few - the smaller moons and asteroids - cooled quickly and soon settled into their final shapes and guises, preserving the oldest rocks we can find, rocks that tell us of the early days of the solar system. On other planetary bodies, these formational processes continued for hundreds of millions of years. For many, including the larger planets and the earth, the changes continue at some level right into the present.

At first the earth was an absolutely awful place, a molten or nearly molten mix of many different materials in constant motion, without oceans and without an atmosphere. As the mix slowly stirred itself, continually forcing materials to the surface, the lighter elements (such as hydrogen and helium) and the heavier but unreactive elements (such as xenon, neon, and krypton) escaped into space, driven off by the intense heat. This process is called **outgassing**. Other gases were either held by gravitational pull (the heavier gases of our first primordial atmosphere) or reacted with solid elements to become minerals (such as oxygen combining to form various oxides). Carried to the surface via thousands of volcanic vents, water vapor quickly would have become a major constituent of the early atmosphere. The moon's weak gravitational pull allowed all of its gases - and its water - to escape during this process. On the largest planets (Jupiter, Saturn, Neptune, and Uranus) the immense gravitational pull still holds even the lightest of these gases in thick, murky atmospheres.

At some fairly early point, the lighter solid elements and compounds at the earth's surface cooled sufficiently to form a scum of rocks that gradually grew in thickness to become a **crust**. As the heavier elements (nickel, iron, and others) sank toward the center, they added to the developing core. The surface scum - the crust on which we live-continues to accumulate even today, and continues to be disturbed by movement of the semiliquid material, or **magma**, beneath. The slow churning of magma is responsible for the movement of our present continents, and still delivers new water and gases to the surface via active volcanoes.

During the period of outgassing and crustal formation the remnants of the great cosmic cloud that provided the original materials of the solar system continued to feed the growing planets for a very long time. Their surfaces - and the earth's - were bombarded by enormous numbers of meteorites. The moon and other planetary bodies that cooled quickly preserve a record of that horrendous bombardment. Their pock-marked surfaces attest to the huge numbers of impacts. On earth, however, continuous continental motion and deformation, the formation of new rocks, and the erosion of old rocks have all but destroyed the last traces of this period in geological history.

There are indeed impact sites around our world, but all represent more recent collisions; there may even be one or more in Missouri. It is for this reason that the moon, without water and without new molten material from within to erase the evidence, is our nearest and best witness to this early phase of planetary formation. This is why the

Several unusual geologic structures in Missouri are thought to be impact sites because they have rounded outlines containing intensely fractured and crushed rocks.

astronauts we sent to the moon were trained in geology and why lunar rocks are of such great value. These rocks - and the occasional meteorite that falls from space - are the oldest rocks we can find. Meteorites may be the only bits of our solar system's original cosmic cloud to which we will have access for some time.

Closer to home, in southern Missouri, several suspicious-looking geological structures several miles wide may represent meteoritic or cometary impact sites. Two of the sites - the Crooked Creek disturbance in Crawford County (10 miles south of Steelville and 3 miles east of Cooks Station on Highway VV), and the Decaturville disturbance in Camden County (9 miles south of Camdenton on the west side of Highway 5) - are characterized by intensely fractured and crushed rocks. They even show the remains of the folded rings that are more clearly visible in such relatively fresh meteorite craters as those near Odessa, Texas, and Flagstaff, Arizona, or those on the moon. However, similar crater-like features can also arise from deep volcanic explosions, which would therefore be called **cryptoexplosive** or **cryptovolcanic** events (crypto = hidden). The presence and orientation of small, conical structures, called **shatter cones**, in the ancient sedimentary rocks at the two Missouri sites seems to point to an impact from above. In this case the structures would be more properly termed **astroblemes** (astro = star; bleme = shot or wound). The absence of meteoritic fragments makes this conclusion less certain, but does not rule out cometary impacts. Since comets are largely ice, they leave little solid evidence of their passing except for such craters.

While the origins of these structures are shrouded in mystery, we do recognize that both are extremely old, dating back at least to the Silurian or Devonian, but not old enough to have been formed during the same period as the moon's craters. The Decaturville and Crooked Creek astroblemes have been much eroded during the hundreds of millions of years since their formation and are now well-disguised by modern forest and field. Neither is at all obvious to the untrained eye, nor would either warrant inclusion on your average tourist itinerary. Part of the Decaturville structure, though, is exposed in a new roadcut on Highway 5, just south of the village of Decaturville.

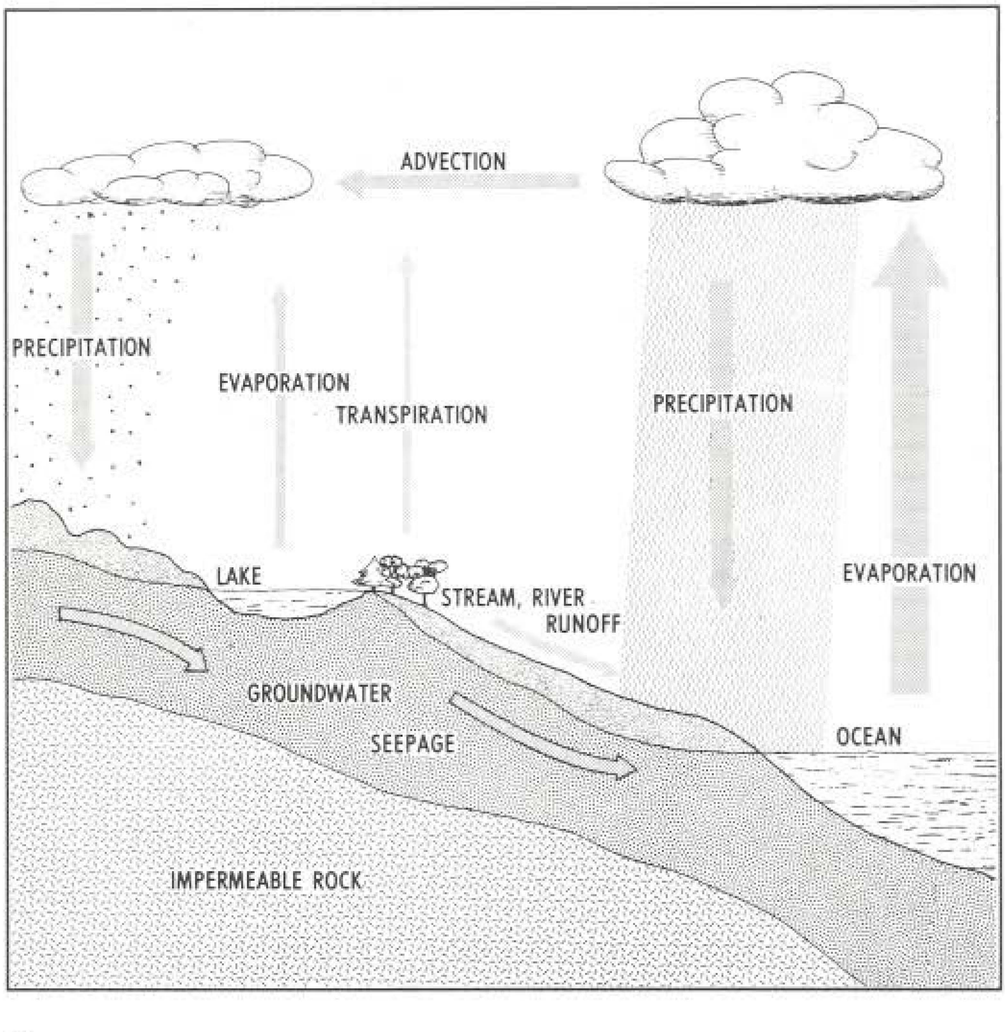
The Earth's First Ocean

Once the surface of the earth cooled sufficiently, water vapor finally began to condense as clouds, and eventually return as rain. This first evaporation-condensation-precipitation pattern has continued ever since and is referred to as the **hydrologic cycle**. The hydrologic cycle delivers all of our freshwater and makes life on land possible. Evidently only a relatively short period of time (geologically speaking, of course) was required for the hydrologic cycle to have established some kind of ocean, because stromatolites and their associated sedimentary rocks - the oldest banded iron formations - date back at least 3.8 billion years. For stromatolites and banded iron rocks to form, one must have standing water, even if it is not worldwide in distribution. Hence we may assume that water began collecting in depressions significantly earlier than the appearance of these formations, probably between 4 and 4.5 billion years ago.

The erosional effects of the early hydrologic cycle cannot be overestimated. Nothing protected the barren rock surfaces of the planet from the endless rain, a rain that likely fell unabated for millions of years. Comprised entirely of distilled water at first (the natural consequence of evaporation and condensation), the oceans, clouds, and falling water picked up enormous quantities of gases from the primordial atmosphere. These gases, after combining with the water, would have formed an enormous number of chemical compounds, including various acids. Once running across the surface, the water would have dissolved salts and metals, leading to all sorts of spontaneous reactions and producing an array of chemical compounds, including, eventually, even complex organic compounds.

Bolstered by its complex brew of chemical compounds, the constant overland flow attacked the surface physically as well as chemically, breaking it apart as it dissolved its minerals. The runoff carried huge loads of surface materials, from grains of dust to boulders as large as a car, depending on the volume of water. All the dissolved materials and sediments ended up in low places and basins, to be abandoned by the water as it reentered the hydrologic cycle. Gradually the seas collected an array of dissolved minerals, salts, gases, acids, alkalis, and other compounds. Gradually, also, its igneous floor was buried beneath sediments.

Among the products of the complex chemical reactions in this primordial brew - triggered by constant lightning, the sun's high-energy ultraviolet light, and the intense heat of volcanoes and meteoritic impacts - could be found all sorts of carbon-based or organic compounds, including every chemical building block necessary for life. Even amino and nucleic acids, the basic components of proteins and the genetic code, were found in early seawater. It is in this oceanic concoction that living things first appeared. Nothing on land could have been the least conducive to the chain of events that led to the creation of the first cells. While several scenarios might be used to explain the events leading to the development of simple bundles of complex chemicals capable of reproduction (that we may therefore define as living), we merely state here that life did appear in the oceans in a very simple form, probably by 4.2 billion years ago.


ADVECTION
PRECIPITATION
EVAPORATION
TRANSPIRATION
PRECIPITATION
EVAPORATION
LAKE
STREAM, RIVER
RUNOFF
GROUNDWATER
SEEPAGE
OCEAN
IMPERMEABLE ROCK

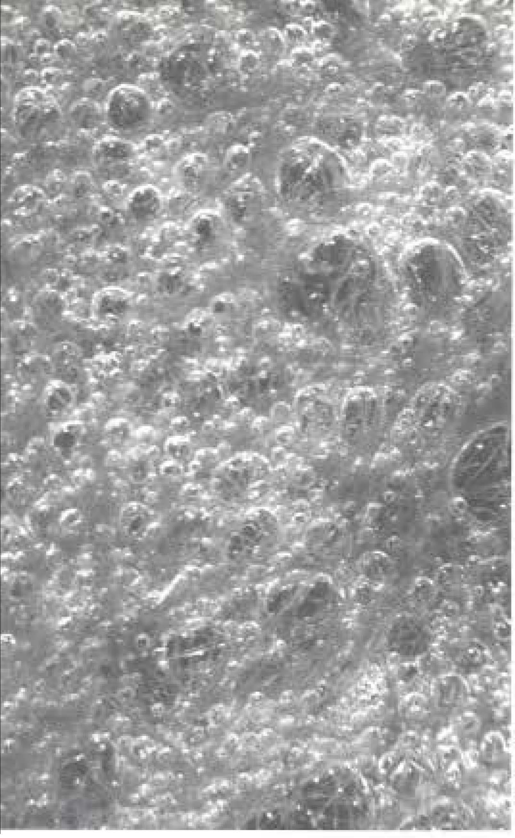
The hydrologic cycle continuously circulates water from the ocean to the atmosphere to the land and back to the ocean, powering the "geologic engines" of weathering, erosion, and depositon.

The First Appearance Of Life

As more and more water was released to the atmosphere by ongoing volcanic events, the sea and its sediments deepened. Salts continued to be added in abundance, and organic evolution proceeded. The first living things may or may not have been exactly like the bacteria of today, but they were certainly capable of living without oxygen, and they must have used similar chemical processes to acquire nutrients and energy. For food, they took advantage of what lay all about them, feeding heavily on the rich oceanic mixture, primed with complex organic compounds. No athlete's supplemental drink could have been better designed for growth and reproduction. And obviously, as abundant as the food supply must have been at first, there was no compelling need to be very careful in extracting nutrients and energy from it. The first cells probably relied on simple fermentation, an inefficient, energy-wasting process that generally produces methane gas as a waste product.

As so often happens when living things are turned loose on a seemingly endless food supply, these first wasteful, opportunistic feeders soon consumed the bulk of their originally superabundant food supply. Inevitably, their populations crashed as a balance was struck between their rate of consumption and the rates of the chemical reactions necessary to produce their organic foods. The only way to be freed from this reaction-rate constraint was to somehow incorporate the necessary chemical reactions directly into the bacterial chemical system. And that is precisely what happened next.

To bypass the inefficiencies of the random reactions that happened around them constantly, but at a limited rate, it was necessary that living things gain control over both the kinds and the rates of reactions. Such control would allow the necessary organic materials to be assembled with greater efficiency. Control over the kinds of reactions came with the emergence of protein catalysts, each of which accelerated a specific reaction. Of course, in order to optimize the output of those reactions, the bacteria needed an ample supply of simple raw materials from


Jon Hawker

Even simple green algae, such as these, release enormous quantities of oxygen during their photosynthetic reactions.

which to build complex compounds. This was a relatively simple problem because raw materials were everywhere around them in the chemical milieu of ocean and atmosphere. More importantly, however, they needed a reliable energy source with which to drive the reactions, because complex organic molecules don't simply assemble themselves.

The building blocks of complex organic compounds must be thrust together (figuratively, of course) using a great deal of energy. In the ocean around them that energy could be provided by lightning, ultraviolet light, or the heat of volcanoes. None of these would be an appropriate energy source for a living being. For obvious reasons volcanic eruptions and lightning would be difficult to incorporate into cellular processes, and ultraviolet light can be intensely damaging. It should surprise none of us to learn that several kinds of bacteria found the solution in the visible portions of sunlight, the most powerful and reliable source of energy on earth's surface.

Other species of bacteria mastered the technique of extracting energy from chemicals, what we call **chemosynthesis** (= to make with chemicals). Although they could live in light, chemosynthesis allowed these bacteria to become dominant in situations where light was absent, such as around deep ocean vents, the black smokers, for instance. Clearly such sites were much more abundant early in the Precambrian when vulcanism was rampant, giving chemosynthetic bacteria elevated importance at the time. Despite the usefulness of the chemosynthetic process, **photosynthesis** (= to make with light) became crucial to solving the long-term problem of control over reaction rates, especially as the earth settled down geologically. Today, while chemosynthesizers still construct their organic matter and reproduce using chemical energy, they are restricted to the relatively rare sites where such chemicals can be found in abundance. With sunlight readily available, it is photosynthesis that makes today's biological world go 'round.

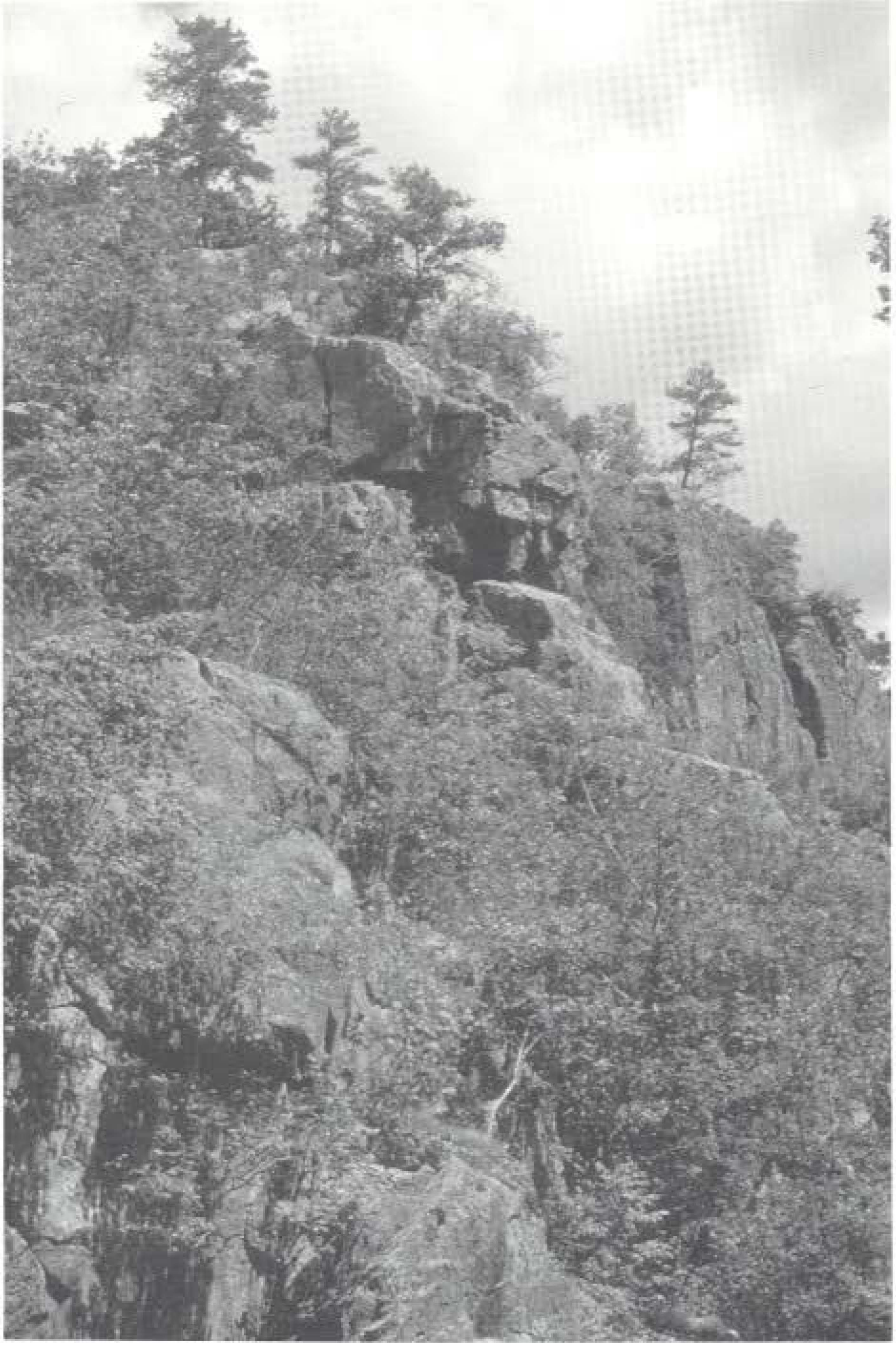
Almost any grade school child who has paid attention in class can tell you that green plants, made green by their photosynthetic chlorophyll, manufacture sugar from carbon dioxide and water, and give off oxygen in the process. The sugar is used as an organic food source; the oxygen to "burn" or respire it. The first photosynthesizing bacteria indeed possessed chlorophyll and were also green, but they were also purple, a consequence of other pigments used to capture light. However, they did not use water, nor did they give off oxygen. Instead, the first photosynthetic bacteria manipulated carbon dioxide and hydrogen sulfide - the foul gas that emanates from your tightly bagged egg salad sandwich - and they gave off bright yellow crystals of elemental sulfur.

Such bacteria still exist on the earth today in a few unique natural environments, such as coastal mudflats, where hydrogen sulfide is readily available, but oxygen is not. Green plants and cyanobacteria both require oxygen, but there was no oxygen in the early atmosphere. However, there was an abundance of hydrogen sulfide. Consequently these green and purple sulfur bacteria thrived. It was hundreds of millions of years before the cyanobacteria finally overcame the chemical obstacles and replaced hydrogen sulfide with water. In the process, they produced enough oxygen to satisfy their own local needs, and, with the excess over an exceedingly long period of time, eventually converted the atmosphere to the mix we have all grown to need and love.

The Appearance Of The Continents

Meanwhile the seas continued to grow and to spread over the surface of the earth. By 2.5 billion years ago, water covered all but the highest portions of the thickening crust. Nothing like our continents existed at first. It probably took a billion years of crustal bumping, grinding, and erupting to bring enough material together in places to actually build continents as we might recognize them. Like ice flows on a river, drifting slabs of crust shoved against one another constantly, pushing great sections of rock up and over the edges of other slabs, folding, breaking, and over-riding. In this way the small bits of crust were nearly all consumed by the large, only to be torn apart once again by the flow of molten magma beneath. The magma often broke through to add material to a continental mass directly. In the end, this crustal "cannibalism" gave rise to a system, called plate tectonics, in which supercontinents were assembled from smaller continents, then were rifted apart once again into smaller ones. The system continues even today. The earth was well along in the development of this system when magma finally erupted through one of the continental masses to produce our St. Francois Island chain.

Open to the incessant beating of rain, sun, and wind, as much as 6-8 thousand feet of hard, resistant St. Francois rocks were slowly reduced to grains of sand and bits of mud, then washed from the islands. Whenever the debris was allowed to dry it would have been blown about freely, creating huge dust and sandstorms, and, in some situations, collecting as massive areas of dunes. Protected by only the most primitive forms of terrestrial life, the fragments were eventually swept into sand and gravel bars along small creeks and rivers, and soon filled the narrow valleys between lowering mountaintops. Carried to the sea, the sediments were deposited in deltas building in the zones where fresh and saltwater mixed, or dropped in the bottoms of stagnant backwaters and quiet bays. Some of the stony debris was washed along shore by tide and wave action, where it was tossed onto cabana-less beaches backed by buggy-less dunes.



Jon Hawker

Most of the older St. Francois Mountain rhyolites have eroded away, but deep layers are exposed at places such as Prairie Hollow Gorge.

Perhaps 500 million years of this kind of weathering was necessary to reduce the rugged and once-scenic volcanic islands to low, rounded domes of smooth rock perhaps 2,000 feet above the sea floor. By the end of this first major erosional phase of the Ozark uplift, the islands had almost completely disappeared beneath their own sediments and the sea. Most of the oldest rhyolites were broken down and carried off during this period, exposing the deeply buried granites of the younger plutons. Today, these ancient granite domes - such as Elephant Rocks - with their scattered patches of leftover rhyolite are among the most prominent and visible features of the southeastern Ozark landscape.

The First Ozark Sedimentary Rocks

As a result of the constant assault by sun, wind, and rain, the St. Francois valleys and the floor of the surrounding sea were all smothered by hundreds of feet of mud, sand, and fine gravel. Washed clean of its tiniest particles by current and wave, then slowly compressed under the weight of other material yet to come, the gritty sediment would become cemented by a variety of minerals to form the first, the oldest beds of a major sedimentary rock in Missouri, the Lamotte Sandstone.

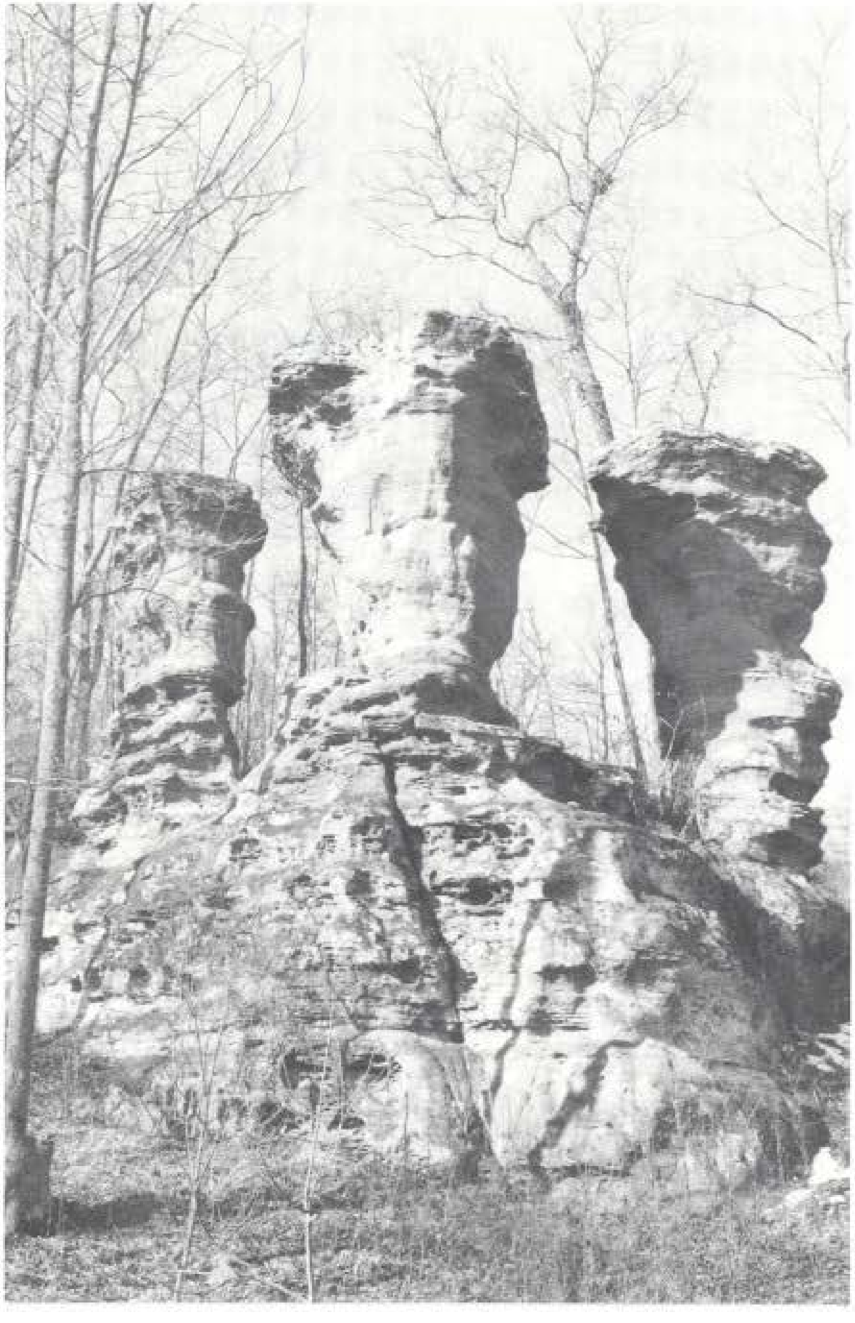
Composed almost entirely of stream- and beach-tumbled quartz crystals released from nearly half a billion years of weathering granite, the Lamotte varies from smooth and fine-grained to coarse and pebbly. Its banded colors grade through dull shades of white, gray, and brown, to a brilliant red-orange. Best observed at Hawn State Park, in Ste. Genevieve County, the 500 million-year old strata have since been cut by erosion into deep, steep-walled canyons, spires, arches, and natural bridges. The bare faces are sporadically tinged with mineral and organic stains of black, blue-green, or magenta from various types of bacteria, algae, and dissolved minerals that have penetrated the porous surface. When attacked by frost, wind, and rain today, the Lamotte yields the very same range of fine and coarse sands originally given up by its parent granites more than a billion years ago.

Named for one of the first French mining engineers to work in Missouri, the Lamotte Sandstone is a very distinctive sedimentary rock, both because of the time and manner of its formation, and because of the characteristics of its source material. As the initial Ozark uplift wore away, few complex forms of life had yet evolved in the oceans and probably only the simplest occurred on land. True soils, soils composed of a mix of mineral and organic matter, might have begun to form in the sands under rare circumstances, but most rock debris simply lay bare wherever it collected, scattered by the wind or tossed by the waves.

In deserts, sheltered sand flats, and quarries today, the upper layers of sand are sometimes held together as if the grains had been glued. This mat is generally formed of some combination of interwoven fungal strands, chemosynthetic bacteria, cyanobacteria, and more advanced forms of algae. The microscopic network of fungi lace through a large volume of sand grains, collecting water and dissolved minerals as they spread, then channel them to the bacteria or algae. These microorganisms use the mineral material in the construction of their own cell contents. In return, they supply the parasitic fungus with food, since fungi do not have photosynthesis or chemosynthesis and cannot produce sugar. The secret to the success of these relationships is the delicate balance between fungal growth and bacterial synthesis; the fungus is always on the verge of eating the goose that lays the golden egg.

Simple relationships such as these are common under harsh conditions today and likely existed in the Precambrian, but we have little direct fossil evidence to support the supposition. We do know that many of these relationships can survive long periods without moisture, exposed to intense sunlight. There is no reason to suppose, therefore, that similar relationships could not have formed in Lamotte sands, and that some overcame the attachment problem to pioneer bare St. Francois rock surfaces as our first Ozark lichens.

The Lamotte Sandstone, here eroded into columns called The Candelabra, near Fredericktown, is Missouri's oldest sandstone.



Jerry D. Vineyard

The Precambrian Era saw the creation and first uplift of the Ozark dome, the first of three subsequent erosional phases that would eventually wear the dome to a low coastal plain, and the first life definitely known to have inhabited the developing Ozarks.

The First Multicullar Life

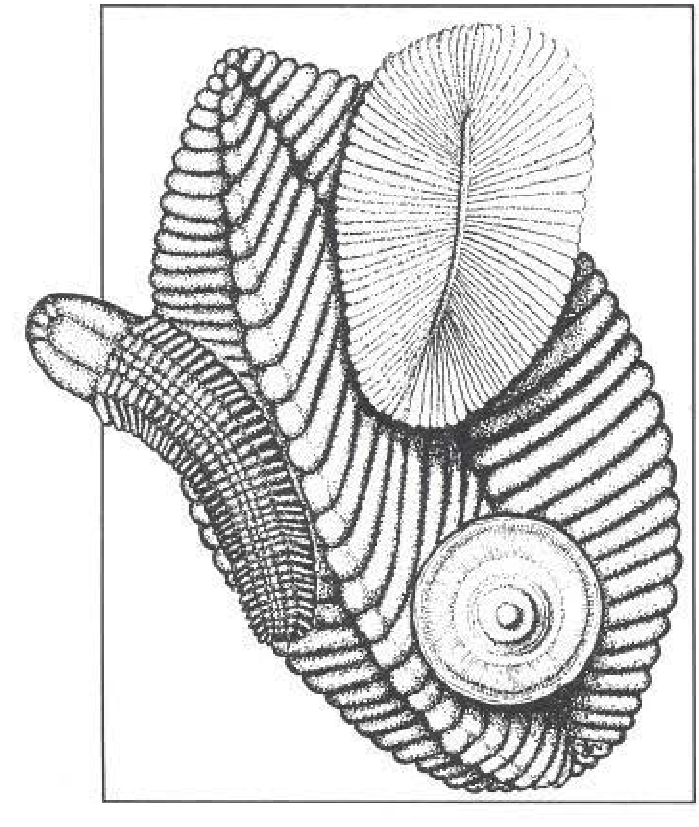
Although ocean waters washed over the Ozark area on numerous occasions, the environmental conditions and life forms changed with each inundation. The changing conditions greatly altered the type of sediments that collected on the ancient sea floors of each period. Those conditions can be interpreted today, both by the types of rocks that developed from the sediments of the day, and by the kinds of fossil plants and animals that are found in their layers.

Few fossils are found in the Lamotte Sandstone, but not because there was no life at the time of its formation. The coarse texture of the sandstone indicates that it was deposited where water was neither still nor calm. Wave and current action not only carried off the finest particles, it also turned the sand into a powerful abrasive. Anyone who visits Johnson Shut-Ins State Park can see how water-tumbled quartz relentlessly etches solid rock and polishes stones to a glassy sheen. There are few creatures that can withstand this kind of persistent grinding. Once dead, their remains are also quickly pulverized; hence, few fossils remain. The impressions of a few stout **brachiopods**, also called lamp shells, have been found in the Lamotte Sandstone, but little else seems to have survived the battering administered when the sediments were laid down. This group of filter-feeders are mollusk-like creatures with wavy, hinged shells similar to a clam's, but attached to solid surfaces by short stalks. They are among the most common and easily recognized of Missouri's early animals. But they could not have been the earliest.

Water-tumbled quartz relentlessly sculpts solid rock and polishes stones to a glassy sheen at Hahns Mill Shut-Ins on the Castor River.

Jerry D. Vineyard

Clearly life did not simply arise in these early Missouri seas suddenly and only as well-established and highly evolved kinds of brachiopods. From fossil evidence all over the world we know that less complex multicellular forms developed much earlier from even simpler ancestors. Unfortunately, Missouri rocks that accumulated during this long period of earth history preserve none of these intermediate forms, so the fossil trail of life in the state begins with the cyanobacterial stromatolites, then leaps a billion years to brachiopods. Certainly, much must have been happening, biologically, during this late Precambrian period, because Cambrian fossils are suddenly diverse both in body form and in lifestyle. As examples, animals with some form of "shell" or hard external covering are notably infrequent in the Precambrian, as are true burrowing species, yet both appear in extraordinary numbers in the early Cambrian record. Fossils that are indisputably red and green algae are scarce in Precambrian strata, but common in Cambrian rocks. Fortunately, as we said earlier, impressions of some of the earlier organisms from the fine-grained sedimentary rocks of Canada and Australia have filled much of the gap.



Fossils of Vendozoans from the Precambrian reveal creatures unlike any living today, including the ¾ inch wormlike Sprigginia *(left), the one-inch, disc-like* Cyclomedusa, *the two-inch* Dickinsonia *(upper right), which sometimes reached a colossal 36 inches across, and the triple-vaned* Pteridinum *(rear).*

To date, useful numbers of fossils from this period (thousands of specimens, actually) have been recovered only from the Ediacara Hills of South Australia. Termed the "Ediacaran fauna," the stony impressions come in a number of shapes and sizes, and hint at a variety of feeding techniques. While most are only 1 or 2 inches long, quite a few are over a yard across, larger than any known Cambrian animal. Some seem to resemble the feather- or fern-like, stalked filter-feeders of modern seas called "sea pens." Others are almost worm-like or jellyfish-like. All show significant differences from any species encountered since.

In fact, these animals seem to have no modern counterparts, nor do they much resemble anything from the Cambrian. From the evidence available today it is highly likely that these first animals belonged to a major group of animals unknown since the close of the Precambrian, a period sometimes referred to as the Vendian Period; hence the name Vendozoa (= "Vendian animals") for the strange group. The Vendozoans seem to have passed into extinction at or shortly after the end of the Precambrian and left few if any recognizable descendants. By then, however, the seas were swarming with whole new groups of living things.

The Blossoming Of The Cambrian

The sunny seas lapping at St. Francois Island beaches during the period of Lamotte Sandstone deposition, the Cambrian Period of the Paleozoic Era (beginning some 500 to 600 million years ago), were warm and rich with nutrients. Undoubtedly a paradise for marine creatures, similar seas all over the world became centers of evolution for the rapidly diversifying life of the Paleozoic, literally the period of "old animals." The next 300 million years saw a vast series of narrow channels, sand bars, deltas, mud flats, algal and bacterial reefs, and shallow bays develop around the shores of the St. Francois Islands.

Living conditions along protected coasts of the islands must have been far different from those on windward, wave-battered rocky coastlines where only brachiopods could cling. Safe and secure in the warm lagoons behind protective bars and reefs, plants and animals would have been able to develop large populations and diverse communities. From the ocean waters sweeping over the reefs and into the lagoons, these plants and animals withdrew enormous amounts of the mineral calcium carbonate, the stuff of Tums and chalk, and processed it into skeletons, stalks, and shells. As they died, their remains settled to the bottom to be slowly squeezed and cemented into another type of sedimentary rock known as limestone, one of two common so-called **carbonate rocks**. The other familiar type is often referred to as **limestone**, but is more correctly called **dolomite**.

Today there are uncountable numbers of Cambrian fossils in the carbonate rocks exposed along Missouri's highway roadcuts and streamside bluffs. Such exposures reveal much about the developing Ozark marine fauna, including numerous forms of algae, sponges, worms, bryozoans, crinoids, brachiopods, trilobites, snails, graptolites, and cephalopods. In fact, the broad series of Missouri carbonate rocks preserves one of the most complete pictures of ancient marine life available anywhere and is a dream come true for the invertebrate paleontologist. What is most impressive - and most mysterious - about all these fossils of animals with shells and skeletons is where they all came from. There are practically no shelled animals in the Precambrian fossil record; those that have been found are tiny and difficult to interpret (in fact, they are usually called simply "small, shelly fossils" by researchers). The Cambrian seas seem to have suddenly exploded with shelled creatures. This is a topic about which much has been and more will be written as new revealing discoveries are made.

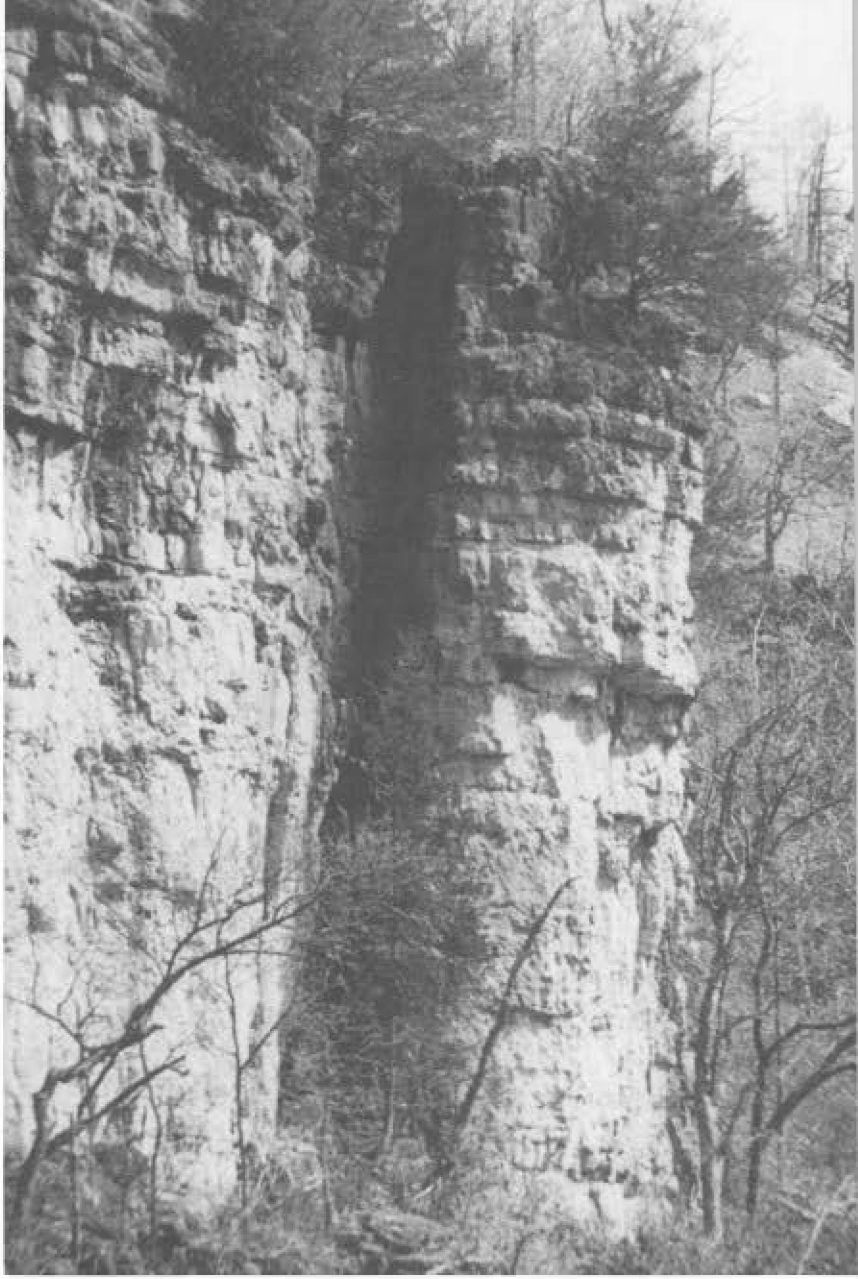
As we look at a roadcut, however, it is obvious that most of the material in the rock is not made of shells, skeletons, and stalks. Some other process must have contributed greatly to the formation of the thousands of feet of carbonate rocks present in Missouri.

Calcium carbonate is soluble in water, but even more easily dissolved by a weak acid, such as carbonic acid. This mild acid is nothing more than carbon dioxide, the gas we and most other livings things exhale, and the gas produced by the burning of coal, natural gas, gasoline, wood, and other fuels, dissolved in water. Seltzer water and soda pop are two forms of carbonic acid solution that are familiar to most of us. Limestone dissolves quickly in carbonic acid. The more plentiful the carbon dioxide in the water, the more easily the calcium carbonate dissolves. As the most common mineral form of calcium carbonate, known as **calcite**, dissolves, its chemical constituents disappear into the solution. Only when the water evaporates, or the carbon dioxide leaves the solution, making it less acidic, will the mineral form reappear as mineral crystals.

Only when the water evaporates, or the carbon dioxide leaves the solution, making it less acidic, will the mineral form reappear as mineral crystals. Here, calcite crystals form a continuous lining in a cave.

Jerry D. Vineyard

As carbon dioxide levels rise in the atmosphere, carbonic acid becomes more plentiful in the atmosphere and in puddles, lakes, rivers, and oceans - wherever water is available. Under such conditions, the dissolution of the mineral accelerates, soon filling the water to capacity with dissolved calcium carbonate. If the levels of carbon dioxide in the air should fall, the concentration of the gas in water also decreases, lowering the solution's acidity. The solubility of calcium carbonate declines at the same time. As a result, dissolved calcium carbonate will quickly recrystallize out of solution and will settle to the bottom as either the mineral calcite or a similar mineral with a slightly different crystal geometry called **aragonite**. Aragonite is also the calcium mineral typically used by animals to construct shells. Whether in the form of precipitated crystals or accumulated shells, the aragonite is usually altered by pressure and recrystallization into calcite.


Jerry D. Vineyard

Ozark floaters with stiff necks often pass between impressive bluffs composed almost entirely of dolomite.

In those ancient tropical seas, especially in protected lagoons, water could hold very little carbon dioxide. As a rule, gases are more easily dissolved in cold water. For the same reason that warm soda holds little fizz and quickly goes flat, warm lagoons also lost their "fizz." In addition, the abundant sunlight, warmth, and rich nutrient supply would have spurred algae to grow rapidly, absorbing any leftover carbon dioxide for their own use in photosynthesis.

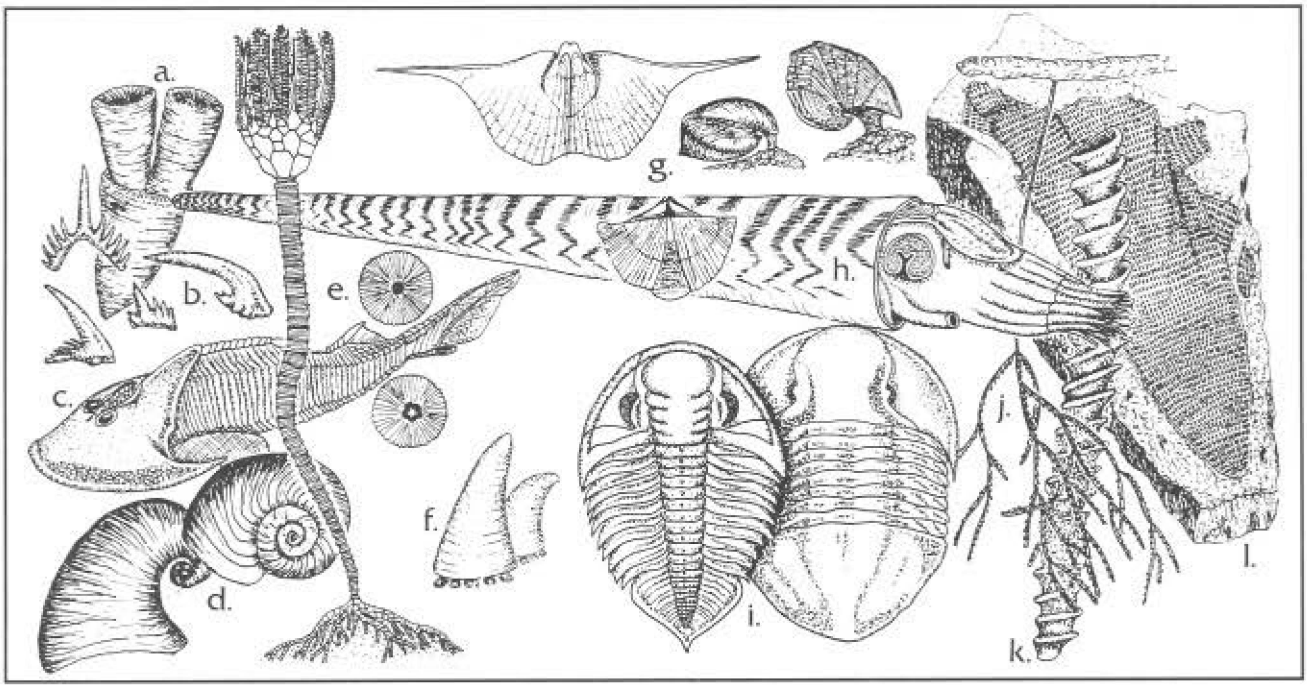
Deprived of its carbonic acid medium, dissolved calcium carbonate would have been unable to stay in solution. As a result, for hundreds of millions of years a gentle microscopic shower of needle-like aragonite or calcite crystals rained upon the ocean floor, burying the shells, the stalks, and the skeletons, and converting all to a soft, limy ooze. Over the eons, this calcium-rich ooze was compressed and crystallized into solid limestone.

Even more familiar than limestone, by sight if not by name, are the dolomites. Similar in appearance to limestone, dolomite's familiar white to gray layers of stone are crushed and mixed with cement to pave many of Missouri's highways, and to help enrich the fields alongside. Ozark floaters with stiff necks often pass between impressive bluffs composed almost entirely of dolomite.

As much as it resembles limestone in appearance and composition, the mechanism by which dolomite forms is something of a puzzle. Like limestone, dolomite is mostly calcium carbonate. But unlike limestone, dolomite also contains a substantial amount of magnesium carbonate. Few marine creatures incorporate appreciable amounts of magnesium carbonate in their tissues, so the mineral was not incorporated into the rock via the skeletons or shells of dead animals. Nor does magnesium carbonate crystalize and settle out of water with the same ease as calcium carbonate. Even though magnesium is ordinarily three times as concentrated in seawater as calcium, it never seems to accumulate in sediments as readily. Where did the thousands of feet of magnesium-rich dolomite layers in Missouri come from?

Dolomite bluffs are familiar landscape features along streams in the Missouri Ozarks. Red Bluff near Davisville is named for the russet-red iron stains that streak the gray dolomite.

Jerry D. Vineyard

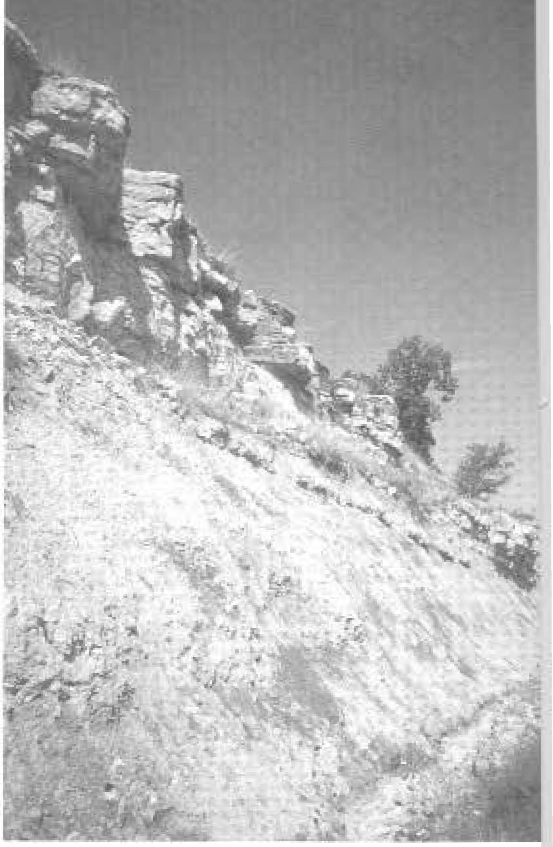


A collage of Paleozoic life from many geological time periods includes: a) a fossil horn coral; b) conodonts, the fossil teeth of soft-bodied, primitive worms, now extinct; c) an armored jawless fish; d) two snails e) whole crinoid and two fossil stem sections; f) two monoplacophorans; g) four brachiopods, including two attached forms with their stalks; h) an ancient squid relative called a nautiloid; i) a pair of trilobites; j) a drifting graptozoan colony; k) the fossil stalk of an extinct bryozoan species, called Archimedes; *l) and the fossil impression of a sheet-like bryozoan colony.*

With the rain of tiny calcium carbonate crystals to the ocean floor, the amount of dissolved calcium carbonate in the seawater gradually dropped. As a result, the relative concentration of magnesium carbonate went up, as much as ten times higher than it would have been under normal circumstances. With such an imbalance, it is possible that magnesium may have begun to creep into the sediments and their trapped skeletal remains, atom by atom, slowly replacing the calcium. Eventually, this would lead to the formation of dolomite where once there would have been only limestone. Although a similar process, on a very small scale, has been observed in some modern tropical lagoons, nothing happening today seems to adequately explain the widespread formation of such massive amounts of dolomite during Paleozoic times. So far, the problem remains unresolved.

The oldest Missouri dolomites belong to the Bonneterre Formation, named for the Old Lead Belt mining town. These sedimentary layers sit squarely on the Lamotte Sandstone and are actually mixed with the Lamotte sands and gravels where the two formations meet. Although the Bonneterre is called a dolomite, the true nature of any rock is highly variable and depends on what was happening when its sediments were deposited. For example, in some places the Bonneterre actually contains layers of a nearly pure, pinkish limestone called "Taum Sauk Marble." Such differences in sediment layers illustrate another characteristic of ancient sea floors; they reflect what was going on ashore as well as what was happening in the ocean.

For instance, heavy rains on land can carry large amounts of sand into the water, mixing the debris of erosion with the rain of calcium carbonate crystals and the remains of marine life. As the materials accumulate, they may produce sandy limestones or sandy dolomites, or limy sandstones or dolomitic sandstones, or any combination in between, depending on how much of each component is mixed in. Similar to the formation of sandstone, the slimy muds that settle out in quiet backwaters and deltas may ultimately be compressed into the soft sedimentary rock known as **shale**. In some places the Bonneterre also exhibits thin beds of shale, composed largely of this type of compressed and cemented mud.


Jon Hawker

Because the lower layer of shale is much softer than the limestone above, it weathers away much more quickly.

After a heavy flood, such mud can mix with any of the other ingredients to yield shaly limestones, shaly dolomites, sandy shales or limy shales, and every other possible blend of dolomite, limestone, sandstone, and shale. During dry periods, the limestones and dolomites would likely be laid down in nearly pure form, with no contamination from the shore. If the loss of carbon dioxide from ocean water slowed because of a cooling trend, then less calcium carbonate would drop out, and limestone formation would slow. In turn, this might affect the rate at which magnesium carbonate crystallized out, affecting the production of dolomite, and so on. Thus sandstone, limestone, dolomite, and shale are all relative terms. They seldom exist in what might be called a "pure" form. Each thin layer of rock is almost always of slightly different composition from the ones above or below.

Although life in the Cambrian was not yet especially diverse when these sediments were accumulating, the Bonneterre Dolomite reveals many more fossils than the Lamotte Sandstone. This may not be due entirely to the evolution of new life forms, but also to the different environments in which each stratum was deposited. Some of the Bonneterre lime built up at the heads of protected bays or isolated backwaters where limited runoff from the land delivered a rich load of dissolved minerals. Other Bonneterre layers formed around the windless shoreline or in protected channels between islands. Most simply settled out on the shallow seafloor directly atop the Lamotte sands. As in today's seas, each environment harbored its own species.

Fortunately, the peaceful conditions in the shallow waters of Bonneterre time sometimes allowed even very delicate fossil tracks and burrows to be preserved intact. From these, it is clear that, besides brachiopods, a fair number of other organisms inhabited the quiet waters of the St. Francois Islands, including sponges, algae, trilobites, and snails. Among these were some strange mollusks called **monoplacophorans**, which had snail- or limpet-like shells, but crept along with segmented bodies. This group of ancient creatures was actually thought to be extinct until the early 1950's, when living examples were discovered in deep waters off the coast of Mexico, obviously alive and well.

Problematical Animals

While most early Ozark marine creatures were easily assigned to one well-known taxonomic group or another, many strange animals have also been found that just do not fit into our present naming system. Some of these remain unidentified and unnamed, with no modern counterparts for comparison. The Vendozoans mentioned earlier are typical of these kinds of problematical animals.

The modern naming or taxonomic system for all organisms is divided into a hierarchy of groups beginning with the largest grouping, the **kingdom**. Most of us can instantly recognize a member of the plant or animal kingdom, but may not realize that the mushrooms and other fungi, the protozoans such as amoeba, and all forms of bacteria are also each in their own kingdoms, a total of five kingdoms. Like a building divided into rooms, then outfitted with closets, cabinets, and drawers by which we might subdivide and organize our belongings, each of the kingdoms is also divided and subdivided into smaller groupings and subgroupings. The **phylum** (plural = phyla) is the largest of these subdivisions, followed in decreasing size by the **class**, the **order**, the **family**, the **genus**, and the **species**.

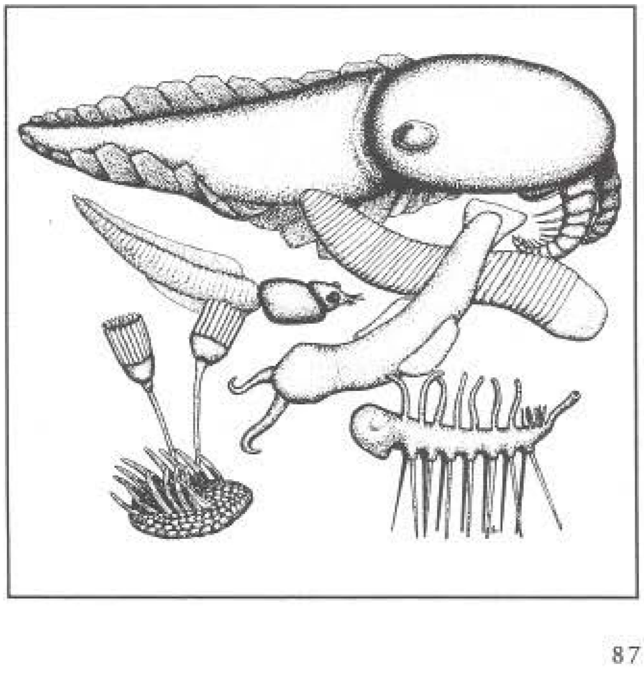
Each kind or species of organism belongs to a group of closely-related species called a **genus**. Similar genera (plural of genus) are lumped together into a family, similar families into orders, and so on. For example, our pet dogs are all considered to be a single species, *Canis familiaris,* with a number of different types of breeds, or body shapes. Our dog's closest relatives - wolves and coyotes - are also in the genus *Canis,* but belong to different species (*Canis lupus* and *Canis latrans,* respectively). Other similar dog-like mammals, such as red and gray foxes (genera *Vulpes* and *Urocyon*), are not similar enough to true dogs to be placed in the same genus, but are enough alike to be placed in the same family, the Canidae.

The dog family, the cat family (Felidae), the raccoon family (Procyonidae), the bear family (Ursidae), and other meat-eating mammals with similar skull and tooth structure are placed together in the order of carnivores, the Carnivora. All of the different orders of mammals, whether they are rodents that gnaw into our garage (Rodentia), bats that fly overhead and eat insects (Chiroptera), or whales that swim thousands of miles (Cetacea), are warm-blooded and share the capacity to produce milk. We put all into a single class, the Mammalia. Other animals with backbones - the birds, reptiles, amphibians, and fish - are in other classes depending on their general characteristics. Those that have feathers belong to the class Aves; those with scales that lay shelled eggs, the Reptilia; and so on. All animals with backbones, whether minnow, toad, lizard, wren, or squirrel, belong to the phylum Chordata, the chordates. Other phyla mentioned so far are the mollusks (Mollusca), the sponges (Porifera), jellyfish (Cnidaria), and trilobites (Arthropoda).

The Cambrian was a period during which nature tried out all sorts of body plans and lifestyles, perhaps just to see what would work. A huge range of unoccupied oceanic environments just begged to be exploited. In response, whole new families, orders, classes, phyla (such as the Vendozoa), and perhaps even kingdoms unknown today, became grist for the evolutionary mill. Some would ultimately succeed at filling one ecological role or another for varying periods of time. Huge numbers of species and groups, once experimentally launched, never quite got off the ground. The monoplacophorans are one such group. Exceedingly diverse in Ozark Cambrian seas, these thorn-like "snails" largely vanished from the earth. Other distantly related forms are also known mostly from Ozark rock layers and may represent some of the region's first endemic species; the Ozarks have been a special place since the beginning of life.

Many of these strange fossil forms, largely unrelated to one another or to anything else, and thus not easily assignable to any recognizable group, had originally been stuffed into a taxonomic pigeonhole of their own, sometimes called the **Problematica**. Like a drawer without a label, way in the back of the museum (which is where many a specimen wound up), early paleontologists had been forced to dump a hodgepodge of leftover animals into this appropriately named umbrella group. Today's researchers recognize that whole phyla - and perhaps even kingdoms - have passed quietly into extinction, just as single species have all along. They recognize the unique character of these organisms and have assigned many of them to phyla and classes of their own; they just can't always agree yet on which goes where.

A number of fossil animals from the early Cambrian cannot be reliably placed in any modern phyla. Among these are, from front, left to right, the scaly Wiwakia, *stilt-legged* Hallucigenia, *flower-like* Dinomischus, *walrus shaped* Amiskwia, Nectocaris, *leech-like* Odontogriphus, *and the predatory giant* Anomalocarus.



Ancient Wealth From Ancient Rocks

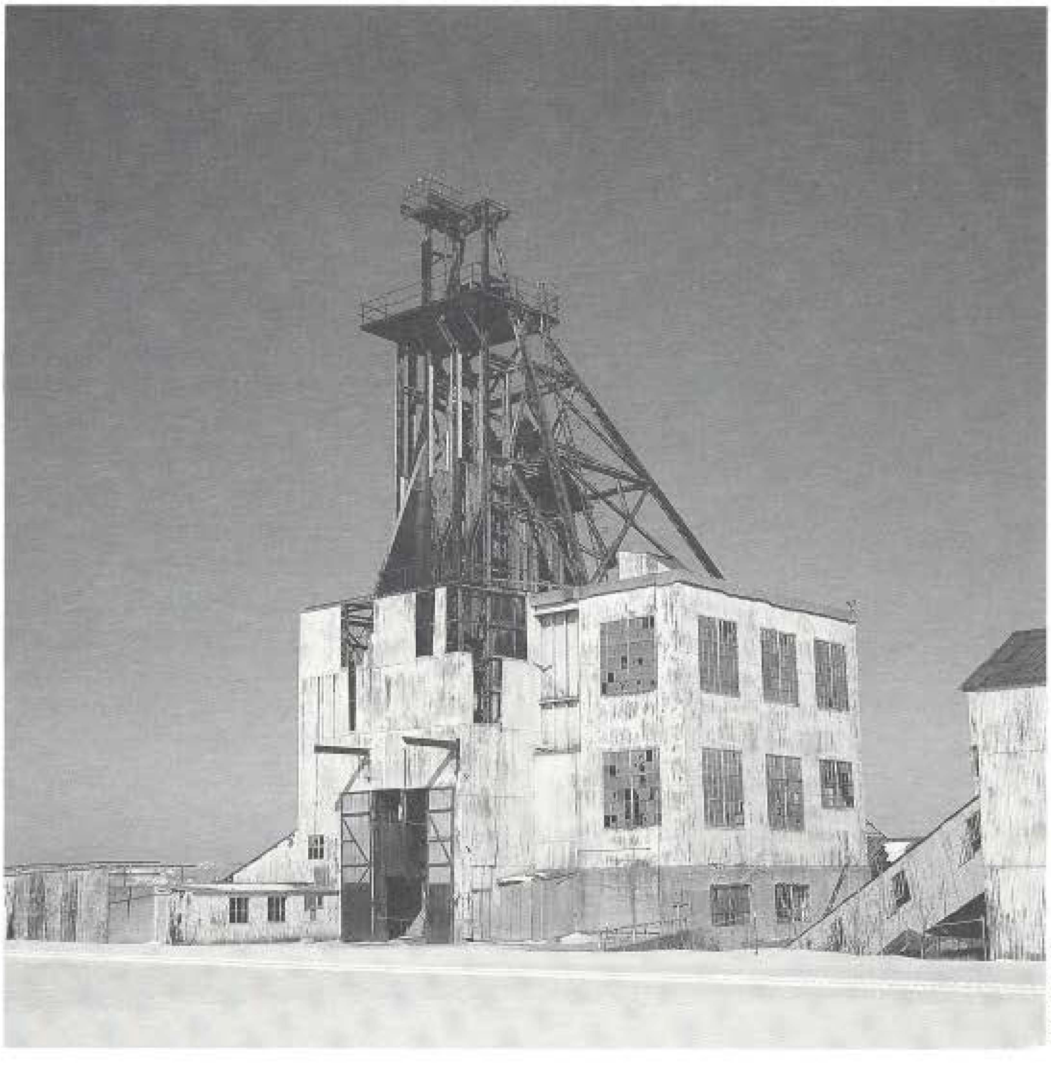
In addition to its paleontological merits, the Bonneterre Formation also provided wealth in the form of mineral deposits. These thick rock layers yielded the bulk of the metal-bearing ores of the Old Lead Belt District, a world leader in lead production for 200 years. When we look at the mineral composition of the earth's crust, we see that only eight elements can be found in amounts greater than one percent - oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium. The fact that lead is generally found in the crust in amounts less than one gram per ton hints that something unusual must have happened to concentrate so much of the element in Missouri rocks. Alternate explanations of the mystery are all variations on a single main theme of crystallization from a strong solution; differences arise mainly as to the composition of the solution, its temperature, its source, and its timing.

One likely way in which the lead mineral, called **galena**, Missouri's State Mineral, might have collected was to have been transported by hot water. This occurs today around active volcanic vents, hot springs, and the deep ocean "black smokers," all of which can yield heavy concentrations of valuable, metal-bearing minerals. We know that several periods of unrest beneath the Ozark dome have occurred since its original formation, perhaps associated with continuing continental movements. Such movements are usually accompanied by injections of magmas (molten rocks) into widening cracks and fissures deep beneath the surface. We don't know exactly when the lead-producing episode occurred - perhaps in the Pennsylvanian as the Appalachians were pushed up to our east, or as recently as the Cretaceous or early Tertiary following other disturbances. We do know that the minerals entered the dolomites millions of years after the Bonneterre strata were originally deposited.

Whichever disturbance was responsible, a very strong brine, perhaps superheated and under great pressure, was forced out by the hot rocks and surged upward, carrying dissolved lead, zinc, and other sulfurous minerals with it. The water and its minerals passed through the older granites, rhyolites, and Lamotte sandstone. Where the porous Lamotte is thin or absent, the Bonneterre is in nearly direct contact with the underlying igneous rock and would have drawn in the metal-bearing water like a sponge. The silvery galena tended to crystallize out in heaviest concentrations along fractures and fissures in the Bonneterre, and these are where the largest cubes of the beautiful mineral have been found. Smaller concentrations of galena are dispersed widely throughout the lower 50 feet of the heavy dolomite.

Similar mineral deposits occur in dolomites of varying age throughout the Mississippi Valley - in Illinois, Wisconsin, and Iowa - an indication of the importance of ancient biological systems to our modern resource base. Economically significant ore deposits often occur where biological communities, such as algal reefs, produced the porous rocks into which these minerals could be transported and crystallized. Without these ancient reefs, we would not have the mineral deposits and we would be without their valuable resources. The best places to steep yourself in the history and operations of lead mining in Missouri are scattered around the Old Lead Belt Mining District at various public and private facilities, such as those in the Bonneterre-Flat River area, and at St. Joe State Park.

The headframe of the Federal Mine at Flat River, now part of St. Joe State Park's Mining Interpretive Center, perpetuates the memory of lead mining that forever changed the landscape in an area known as the "Old Lead Belt."



Nick Decker

Missouri's Rich Oceans And Deep Sediments

Largely flooded by the sea for the next 300 million years, thousands of feet of sand, mud, lime, and animal remains settled over the hard igneous rocks of the drowned St. Francois Islands, almost completely burying them and largely protecting them from further erosion. The soft muck and debris was eventually converted to a wide range of sandstones, shales, limestones and dolomites, generally in layers, or strata.

Each new stratum buried the older, eventually building to depths in excess of 3,000 to 4,000 feet. Today, the strata have been carefully studied and described by geologists, grouped into mappable units, then named for a town or natural feature nearby. For example, as we have seen, the Bonneterre Formation covered the Lamotte Sandstone. Above these, the Davis-Derby-Doerun complex of formations blankets the Bonneterre, and is then covered by the Potosi Dolomite, followed by the even younger Eminence Dolomite, and so on.

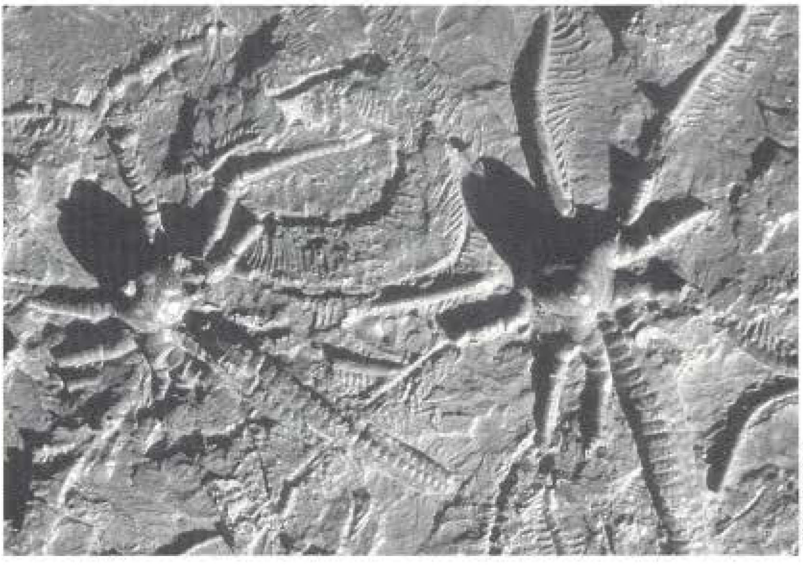
When the Ordovician Period began about 500 million years ago, the seas fell (or the land rose) and rains once again washed the surface of the St. Francois Islands, causing a minor amount of erosion in the Cambrian dolomites and exposing a few of the old granite knobs. The Ordovician ocean evidently advanced and retreated several times, exposing and cutting into the older rocks, even as it laid down new sediments of its own. On the apparently barren land, green and blue-green algae could have been found in moist depressions or in freshwater streams and puddles, while crusty and scaly lichens in a variety of textures and a range of brilliant colors softened what might have otherwise seemed an overly harsh landscape.

As Ordovician sediments and rocks collected in the shallow seas around the islands they preserved a story of slow evolutionary change. During the long span of Paleozoic time, plants and animals continually diversified, the more adaptable continuing on, the less fit dying out. Many of the early experimental forms of the Cambrian had already faded into oblivion, replaced by more resilient creatures that now controlled the marine world.

For example, hundreds of different kinds of **trilobites**, resembling our modern horseshoe crabs more than anything else, scrambled like crayfish over the floor of the shallow Ozark sea. Some swam clumsily between swaying clusters of graceful, flower-like animals called **crinoids**. Like starfish set upside-down on long, slender stalks, the filter-feeding crinoids strained food from passing waters. When they first joined the trilobites in Ozark waters, they were simple and unremarkable as were the trilobites themselves. Over the next 200 million years the crinoids continued to multiply and diversify. During the Mississippian Period, they became one of the most common and ornate forms of life; their fossils dominate many of the limestones and dolomites laid down during this later period. Because of its dominance in the fossil record, the crinoid has been selected as the Missouri State Fossil. Today, only limited numbers of stalked crinoids can be found, and only at great ocean depths.

During the 35 million years of Ordovician time, a growing armada of invertebrate animals developed, including a much greater variety of bryozoans, whose shallow-water colonies left numerous net-like fossils for us to admire. Some fossil Ordovician reefs are composed almost entirely of these simple, multicellular filter-feeders, sometimes called moss-animals. Trilobites, brachiopods, and snail-like monoplacophorans were common, as were cephalopods (octopus and squid relatives) called **nautiloids**. These now sported curved shells in addition to the long, straight shells they had developed in the Cambrian. Colonies of filter-feeding graptozoans, a group related to some early chordate ancestors called **hemichordates**, filtered plankton as they hung from the surfaces of other organisms or drifted at the surface. These left dainty fossils like jigsaw blades called **graptolites** in the fine, dark gray shales exposed along I-55 in northern Jefferson County. Fossils of the first true vertebrates can also be found in other rocks of this period, all members of a group of primitive jawless fish, called **agnathans**, which were similar in appearance to our modern hagfish and lampreys. Later species would resemble toothless sharks or skates encased in armor.

The crinoid, Missouri's state fossil, was a flower-like marine animal that strained food from passing waters.



Nick Decker

Missouri's Hardest Rocks

During the Ordovician, large quantities of a sedimentary rock type called **chert** were formed among the dolomites. In fact, with the exception of the very earliest strata of Cambrian dolomites - the Bonneterre and its next higher companion layers, the thin Davis-Derby-Doerun group - virtually all carbonate rock formations in the Ozarks contain varying amounts of chert. In the dolomites of the Cambrian Potosi Dolomite, and all Ordovician rocks, chert became the one feature truly characteristic of Ozark geology. Recognized by geologists and rockhounds everywhere, massive amounts of chert choke Ozark streams and cloak its hillsides.

Unlike the carbonate rocks in which it is usually found, chert is composed entirely of the compound silica, pure silicon dioxide. The bright crystals of quartz in granite are also pure **silica**, but with a slightly different crystal structure. Other familiar rocks that are rich in silica minerals are shale and sandstone. Much like glass, chert has a crystal structure so fine that it cannot be seen under an ordinary microscope, a characteristic geologists identify by the term cryptocrystalline, meaning "hidden crystal."

Chert can be formed in a number of ways. One type, found in California among other places, is known as "radiolarian chert" and consists of the shells of microscopic marine animals compressed and hardened into stone. The single-celled creatures, called radiolarians, who contributed their shells to the chert, secrete a "glass house" of silica around their soft, amoeba-like bodies. When they die, large deposits of their shells form a slimy mud called "radiolarian ooze" in quiet places on the ocean floor. In time, the squishy ooze becomes cemented into a soft rock that is useful as a filtering agent called "radiolarian earth." After millions of years, this "earth" is further compacted and solidified into chert.

Most Missouri chert seems to have had an origin that differs from the radiolarian cherts of California. Throughout the Ozarks, chert is found as roundish lumps or **nodules** imbedded in limestone or dolomite. Some of these lumps may be flattish chunks the size of a trash can lid or larger and, because they may vaguely resemble the lens of some enormous petrified telescope, are called **lenses**. Nodules and lenses may be joined into a thin, irregular layer that quickly peters out at the edges, a phenomenon referred to as a **stringer**. In some places Ozark chert was formed in definite beds of considerable thickness, sandwiched between strata of sandstone, chert, limestone, or dolomite. In whatever shape or form, the enveloping carbonate rocks were easily dissolved and removed by water flowing over or through the limestone or dolomite, freeing the masses of relatively insoluble chert to litter hillsides, dull plows, flatten tires, and grind canoes.

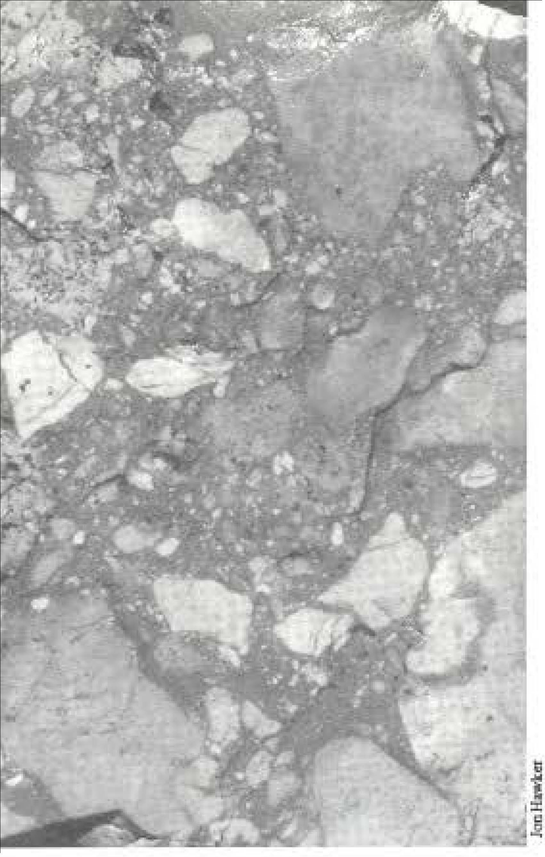
In all probability, chert nodules and lenses formed from the direct crystallization of silica from a wide variety of silicate minerals, in much the same way that a shower of tiny calcium carbonate needles resulted in limestone. The warm ocean waters of the period developed an increasingly concentrated solution of silicate compounds as worldwide weathering of granites, rhyolites, and sandstones continued to provide rich sources of iron, aluminum, potassium, and magnesium silicates. As the seas became overloaded with silicates, bubble-like masses of silica began to crystallize in pockets of the limy muds collecting on the seafloor.

Another means by which the silica in chert accumulated was through the slow replacement of the original structure of rock, wood, shell, bone, or coral. Immersed in strong silicate solutions, the molecules of shell or bone are bumped out, one by one, by silica. Once the more easily dissolved silicates are deposited as silica, they become very insoluble, much like glass. This mechanism has preserved a wide variety of fossils in Missouri, including a broad array of crinoids, sponges, bryozoans, snails, trilobites, and brachiopods. Entire stromatolite reefs, sometimes called cryptozoan (= "hidden animal") reefs, were converted to chert by this process. While a few cryptozoans have been found as early as the Davis and Potosi formations, they do not become common until the Gasconade, Roubidoux, and Jefferson City formations.

The Grand Falls chert forms massive bluffs along Shoal Creek in Joplin's Wildcat Park.

Jon Hawker

One of the more interesting chert formations of Missouri is found around Joplin, especially along Shoal and Turkey creeks in Jasper and Newton counties. Portions of this massive chert bed - of Mississippian age sediment called the Grand


Jon Hawker

The Grand Falls Chert was shattered and recemented during its long formational history.

Falls Chert (from a nice waterfall downstream of Wildcat City Park on Shoal Creek) seems to have been formed peaceably enough, then broken up by some cataclysmic undersea event, only to be recemented by further chert formation. The result is a particularly gnarly (in the old sense of the word) chert when weathered and which, when polished, resembles modern concrete. Exposures and bluffs 50 feet high support one of the rarest, most unusual, and interesting botanical communities in the state.

Often the tissues of familiar marine fossils - and their aragonite shells - were first preserved in calcite, which directly replaced all other materials. The calcite was then itself ousted by silicates in solution, leaving a particularly durable chert fossil. While attractively-tinged chert fossils are found in Paleozoic rocks throughout the Ozarks, there are also logs and chunks of wood petrified by drab brown silica in much younger deposits of the Bootheel region.

The White Sands Of The Midwest

Chert was not the only rock with a character all its own formed during the Ordovician Period. About midway through the period, enormous masses of pure silica sand swept across the Midwest, released by erosive processes cutting into the rising highlands of eastern North America, leveling the juvenile Appalachian, Taconic, and Green mountain chains. These were not the first sands to bury large portions of the sea floor during the Ordovician; they were just the whitest! Earlier, the brilliantly colored **Roubidoux Sandstone** - so highly visible in the roadcuts along I-44, and south of Rolla along U.S. 63 - had been deposited along the shores and in the shallow seas around the edge of the Ozark Uplift. However, the pure white sand that entered now would be the last major sand deposit during the entire Paleozoic; carbonates would dominate rock-forming processes around the Ozarks for tens of millions of years.

Like the older Lamotte beneath, the rusty-red Roubidoux Sandstone of the early Ordovician also seems to have been in constant motion as it was laid down. The grains are worn smooth, as if tumbled;

fossils - mostly hard-shelled mollusks - are few and far between; and there is much rippling and cross-bedding in its layers. Rippling occurred wherever currents swept across a sandy layer and was often preserved if it was gently buried beneath another layer of sediment. Cross-bedding occurs in a rock when its sediments were swept along by a current of air or water in one direction for a time, eroded a bit, then redeposited by another current in a slightly different direction. What we see in a cross-bedded roadcut or stream bank are layers of rock in which the strata do not lie parallel to one another. Unlike the pure silica sand that washed in from the northeast later in the Ordovician, the Roubidoux seems to have had a local origin and is heavily stained by minerals, especially rusty iron compounds.

The white sand that migrated into the Midwest from as far as Canada was the premier silica sand, approaching 99 percent pure silica in many areas; there is simply no other sandstone as pure. Known today as the **St. Peter Sandstone** (named for the Minnesota River, originally called the St. Peter River), these tumbled grains traveled a huge distance from their sources. Along the way, larger particles were either left behind or ground down, and finer particles were carried off by currents. As a result, the sandstone's grains are nearly the same size, what geologists call well-sorted. Each grain was first rounded and polished by abrasion on its water-borne trip, then its surface was frosted by being tossed against its neighbors along midwestern beaches or in the dunes behind. Like the Roubidoux, the St. Peter Sandstone is often massive - up to 100 feet thick in places - and shows much cross-bedding and rippling, but is apparently devoid of fossils.

Exposed along I-55 from Crystal City southward, around Pacific, and here along the eastern end of the Katy Trail, is the soft, easily crumbled St. Peter Sandstone.

Jon Hawker

Exposed along I-55 from Crystal City southward, around Pacific, and along the eastern end of the Katy Trail, the soft, easily crumbled (geologists say "friable") St. Peter Sandstone has been quarried for a variety of uses including as an abrasive in sandblasting, in the production of silicon carbide, for decorative purposes in aquaria and cigarette ash trays, for pumping down oil wells under great pressure to open the strata for easier pumping; in foundries for metal casting, as a water-filtering agent, and for the production of glass. Some is ground to a fine powder and used in the manufacture of pottery and china. Where the rock lies deeply buried, its highly porous nature makes it a valuable water-conducting stratum, or aquifer; when a well-driller hits the St. Peter, his chances of providing a customer with a good supply of water rise.

Life Conquers The Land

By roughly 450 million years ago, during the Silurian and Devonian Periods, life in the oceans had gained a larger number of recognizable animals with modern counterparts. Bryozoans, crinoids, trilobites, brachiopods, and graptozoans flourished in Silurian seas, while primitive horseshoe crabs and other crustaceans gained a foothold. More importantly, various types of corals appeared. Along with sponges, cyanobacteria, algae, and bryozoans, these calcium-secreting animals contributed greatly in the formation of a massive North American reef complex, an enormous structure that would have rivaled the Great Barrier Reef of Australia. This vast biological community developed in the shallow seas from the edge of the Ozark uplift, across Illinois, Indiana, and Ohio northeastward as far as present day Ontario and New York. Snails, clams, worms, cephalopods, and fish abounded along this reef and near the St. Francois shores.

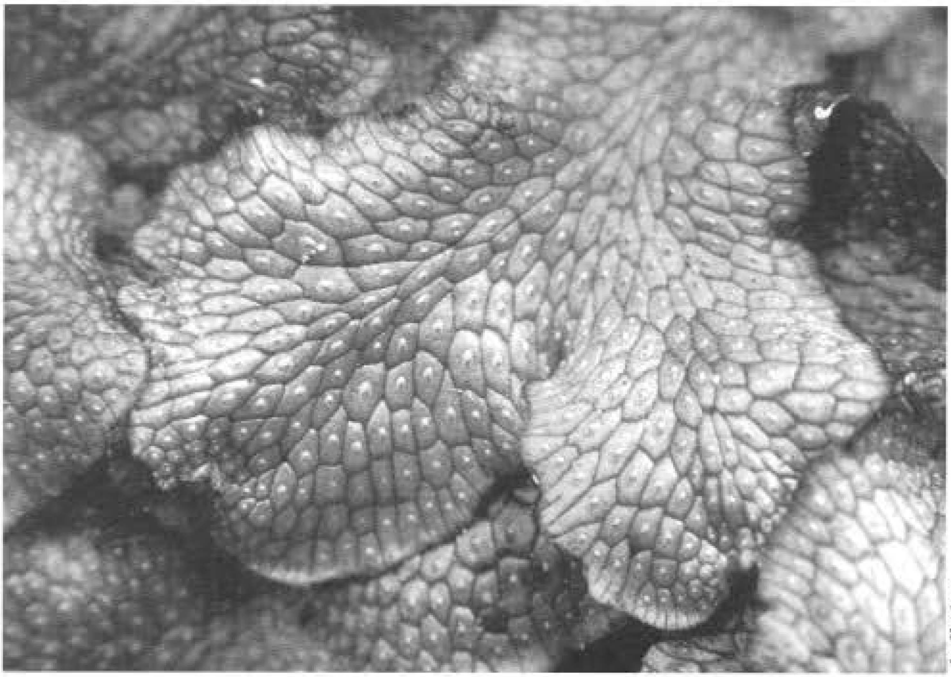
Among these familiar forms there were still creatures that defy identification and resist placement in our taxonomic system. The mysteriously toothlike fossils known as conodonts, for example, are particularly numerous in the rocks of this age. Only recently has this puzzle been partially resolved. Maybe. The highly variable, often microscopic structures may be the feeding parts of worms of unknown affinity. Their variety indicates a huge number of different species occupied the ocean floor from Cambrian times until early in the Age of Dinosaurs. While marine paleontologists have a nearly complete record of teeth from these problematical worms to work with, they can still say very little of how the soft-bodied animals lived. The entire group vanished during the Triassic.

Most of Missouri was above sea level during the Silurian and Devonian. Some of the higher granitic or rhyolitic St. Francois peaks almost certainly reappeared from beneath deep layers of eroding Cambrian and Ordovician rock during the period. Masses of green algae coated near-shore rocks in both fresh and marine waters, and wherever water collected for even a few days a month. More importantly, however, valleys and north-facing hillsides in the late Silurian were beginning to be greened by soft tufts of the very first land plants - short, delicate "forests" of **mosses** and **liverworts**. In mats, clumps, and hummocks, these leafless and rootless plants developed just enough fibrous material in their tissues to overtop the algae. Even without a water-conducting vascular system, mosses and liverworts could rob algae of light and take over wherever a tiny bit of weathered rock collected. As their ability to survive extended periods of drought developed, mosses especially began to cover the St. Francois Islands on all but the driest rock outcrops where lichens still rule today. Liverworts never really overcame the dessication barrier. Even today, most liverworts exist only where moisture and shade are sufficient.

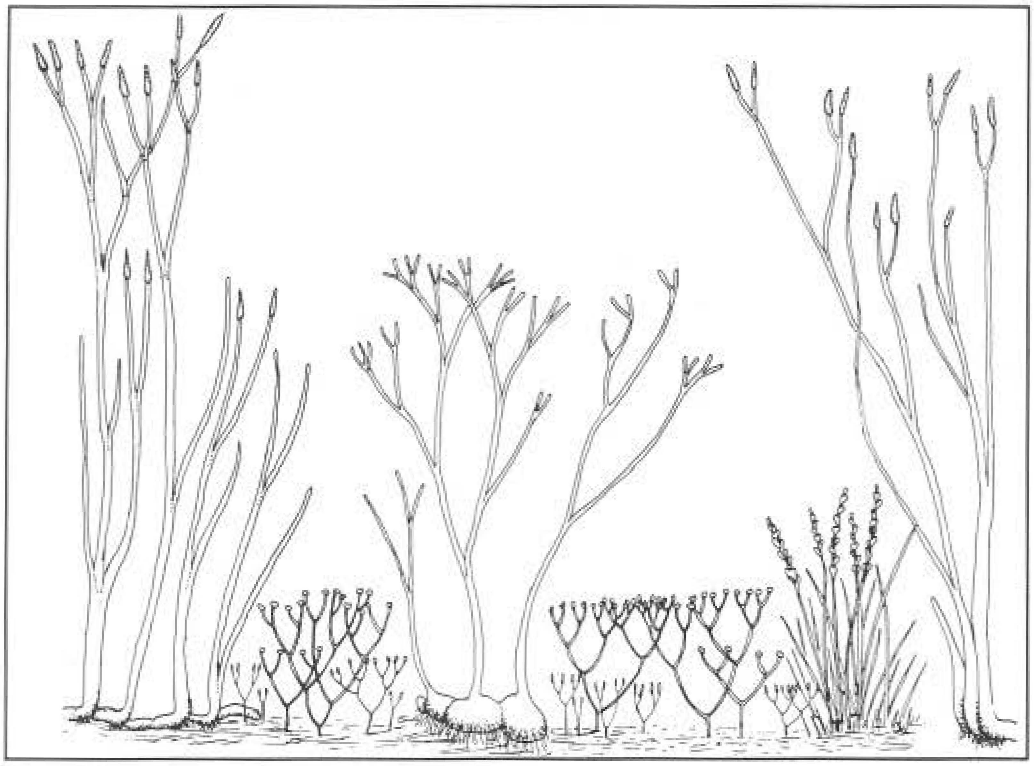
The accumulation and decomposition of organic matter on bare rock surfaces allowed land plants and animals their first opportunity to develop and diversify in a Missouri soil. Various kinds of **flatworms**, **roundworms**, and **segmented worms** not unlike their modern counterparts burrowed through this soil or glided over its surface in search of organic material - or another worm - on which to feed. Soon enough, primitive animals reminiscent of **millipedes** bumbled and nibbled their way through the diminutive thickets and their decaying debris, and were themselves preyed upon by ancestral **spiders**, **scorpions**, and **centipedes**. The first insects - called **collembolans** or springtails, and barely large enough to be seen - scampered away from their enemies on six tiny legs, a body plan that would eventually become the most successful on land.

Members of these same groups - but an entirely different group of species - played out their lives on the hot, windswept outcrops, the Ozarks' first glades, hiding under the cobbles and slabs that accumulated on the surface. These sought sustenance only after rains, or when hot tropical days had passed into tolerable nights. Scavenging beneath the crusty lichens, the earliest kinds of mites might have lived out their short, reclusive lives. Tiny,

Liverworts are still among the simplest of plants - flat sheets of cells without stems, roots, or leaves.



Jon Hawker



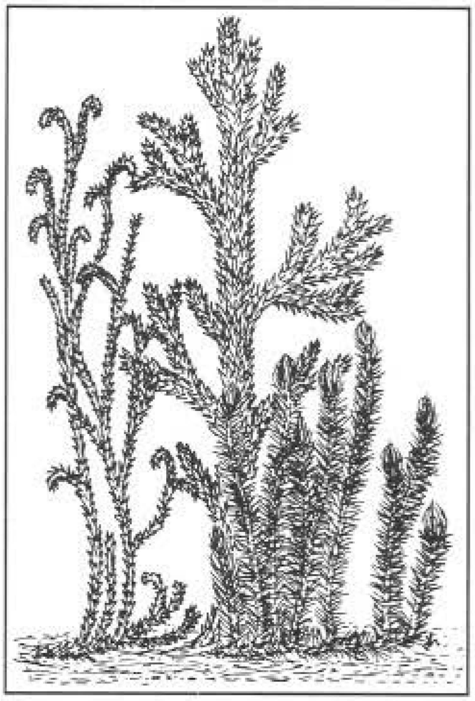
Missouri mudflats of the Silruian and Devonian were home to some of the most primitive vascular plants known, including Rhynia *at 18 inches, the 12-inch* Horneophyton, *and, in descending order by height,* Zosterophyllum, Cooksonia, *and* Stenotheca.

wingless insects similar in appearance to modern booklice probably shared these shelters. Once adapted to freshwater and air, the spread of terrestrial life was incredibly fast, faster even than evolution in the sea had been.

During the 50 million years of late Silurian and Devonian time that followed, the first true **vascular plants** also arose. These plants, equipped with an internal plumbing system capable of efficiently conducting food and water - and providing considerable structural support at the same time - could grow tall and raise their photosynthetic surfaces closer to the sun. As a result, even the earliest, most primitive members of these weird-looking fern relatives thrived. Spore-bearing clumps of leafless stems called *Cooksonia, Steganotheca, Zosterophyllum, Horneophyton*, and *Rhynia* were able to quite literally overshadow the shorter mosses and liverworts. These would reluctantly relinquish their hold on the earth. With no vascular system, and therefore with no capacity for food or water distribution greater than a household sponge, mosses and liverworts were all doomed to a life hugging the ground, in intimate contact with their source of minerals and moisture.

The momentous chain of evolutionary developments that populated the bare land are reenacted throughout the world wherever a build-up of soil allows plant communities to develop on newly exposed rock. Where rocks are barren, only the older, most primitive groups of terrestrial colonists - the lichens and mosses - prevail. As soils develop from bare rock, more advanced groups of vascular plants succeed the earlier pioneers, the same replacement process called ecological succession, mentioned earlier. Modern ecological succession, a process visible anywhere in the Ozarks where granite, rhyolite, or sandstone lie exposed, almost exactly reflects the evolutionary pattern of plant development on the earth. Through the millennia, vascular plants continued their development, adaptation and expansion, and their descendants now dominate wherever a thin layer of soil collects.

The initial step toward domination of the land by vascular plants was taken by the leafless stems of the bizarre species listed above. The next step was the development of thin, leafy outgrowths to improve the photosynthetic efficiency of the upright stems, a step taken in the Devonian by *Baragwanathia, Serrulacaulis, Crenaticaulis, Sawdonia,* and *Asteroxylon.* By the end of the Devonian, these representative species were joined by an enormous number of others with similar transitional construction; the fossil record is rich with variations on these simple themes. Why no further advances in leaf shape or size in the Devonian? With no tall competitors - a virtually empty "tall world" to grow in - there was little pressure for efficiency; almost anything higher than a moss or liverwort would work at first. The main thrusts of evolutionary processes during this period seem to have been the improvement of the "plumbing" system, the development of roots, and the increased efficiency of reproductive structures. Spectacular diversification in size and shape would come in the following geological periods as competition for light and space increased.



Later in the Devonian, simple leaves gave vascular plants increased photosynthetic efficiency. From the left: Sawdonia, Asteroxylon, *and* Beragwanathia.

The first vascular plants all reproduced with **spores**, microscopic capsules carried by air and water that contained but a single cell. Seed-bearing plants would require millions of years more to develop. A tough coating provided the living cell inside a spore with some protection from physical damage as it tumbled along, from being eaten, and from drying out. Conveniently for paleontologists, the tough wall also allowed fossilization. In the Devonian, as is true today, the spores and the plants that produced them fell prey to mites, insects, and other terrestrial arthropods. Some exceptional fossils from this period preserve not only the animals that lived with and on the plants, but also the scars made by those animals as they sucked the sap from the stems or chewed on the tissues. As the plants died they were deteriorated by a variety of decomposing fungi that on rare occasions were also fossilized with an amazing degree of detail.

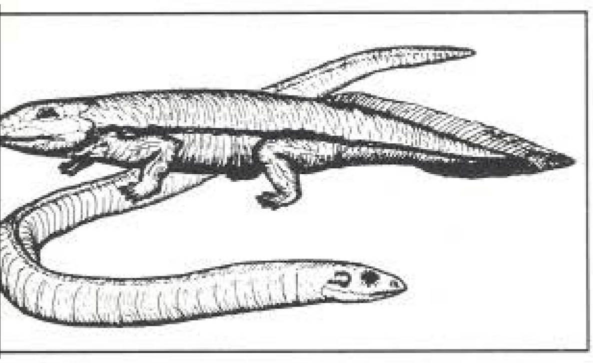
Despite the apparently primitive design of these first attempts at vascularization, similarly simple plants exist even today. The two or three species of **whisk ferns** (which are not really ferns), genus *Psilotum*, are leafless tropical and subtropical species that grow in sandy or humus-rich soils, or on the trunks of tree ferns and palms. Whisk ferns are most familiar as greenhouse curiosities. Similarly, there are perhaps only one or two kinds of *Tmesipteris*, which consist of short stems of simple leaves that hang from tree fern trunks or clumps of humus in Australia and the South Pacific. Both kinds of rootless plants have apparently survived the incredible environmental changes of the past 400 million years.

Animals With Backbones Move Onto The Land

The very first fish with a bony skeleton developed in Silurian and Devonian freshwaters; earlier marine fish were all sharklike and had skeletons of cartilage, the crunchy stuff in your nose and ears. Many of the first freshwater species also had lung-like sacs that were capable of breathing air. In addition, one group - the lobe-finned fishes (similar to the modern mudskippers of Southeast Asia) - had bony hip and shoulder girdles that could support their fleshy fins. It is likely that these peculiar fish were the first vertebrates to crawl out of the water and utilize the growing number of land-dwelling invertebrates as food.

The first animal considered to be a true amphibian also appeared during the Devonian; a four-legged, ponderous, salamander-like creature, over a yard long with a fishy-looking tail. These early amphibians undoubtedly spent most of their time in water; their skeletons were far too weak to have allowed much more than occasional overland travel. In fact, although four-legged, these earliest forms were scaled and possessed skeletons so remarkably fish-like that they are called *Ichthyostega* (= "covered fish"). Nonetheless, their ability to breathe air and crawl about must have been of immense value in moving from pool to pool in search of mates or stranded fish, or rummaging about in the increasingly dense vegetation chasing Devonian insects, worms, or spiders.

Ancient amphibians, such as Ichthyostega *and the eel-like aïstopods were among the first vertebrates.*



Following the Silurian and Devonian, long periods of uplift and erosion occurred in the Ozark region which greatly limited the amount of rock formation. The erosion also eliminated any terrestrial fossils from these periods that might have better illustrated Missouri's most ancient flora and fauna. To construct the story of land plant and animal development just reviewed, we have had to look at Silurian and Devonian rocks from localities outside the state. It is safe to make this slight leap in faith because all known fossil sites, on whichever continent they may be found today, represent vegetative communities that shared the same ancient supercontinent. Climates permitting, identical groups of plants and animals occupied the land from the time of first colonization until the time of the dinosaurs.

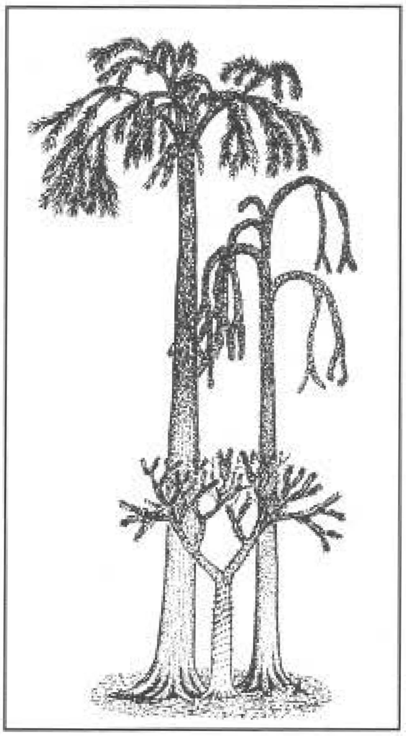
The Evolutionary Explosion Continues

The next 40 million years, the Mississippian Period, was a time of colossal limestone deposition and incredible fossil formation around the Ozarks. Brachiopods and crinoids are so numerous in some Mississippian-age Missouri strata that little else can be seen on slabs of the weathered gray or white rock. On closer examination, however, other creatures can be found. *Archimedes,* the skeleton of a screw-shaped bryozoan found almost exclusively in midwestern strata, shark teeth, and the filter-feeding *Pentremites,* a short-stalked blastoid related to the crinoids, become apparent.

Early in the Mississippian, erosion from the Devonian surface contributed sand and mud to the sediments collecting in the shallow sea; thus the earliest rocks of the period are sandy and silty limestones. However, nearly pure limestone prevails in all later Mississippian strata, an indication that warm, shallow seas of sparkling clear water became firmly established around the Ozark island. To the east, filling the nearby Illinois Basin, these fossiliferous limestone strata are more than 3,200 feet thick.

While only one-eighth that depth anywhere in Missouri, Mississippian rocks are nevertheless of great interest and importance. For instance, the Burlington Limestone, an almost pure calcium carbonate rock, is quarried extensively for agricultural lime in northwestern counties. Another layer, the Warsaw Formation, somewhat higher up, is the source of a hard limestone called Carthage Marble, quarried in Jasper County for building stone. In northeastern Missouri, but especially across the border in Iowa, near Keokuk, and across the river, at Warsaw, Illinois (from whence the formation was named), the Warsaw yields beautiful geodes, prized by rockhounds.

A **geode** is a rounded, hollow mass of stone with inward-pointing crystals. The lining of the geode may be clear white calcite or quartz, purple amethyst, golden pyrite (iron sulfide or Fool's Gold), barite (barium sulfate), or any number of other minerals. Geodes form as mineral solutions seep into cavities in the original sediment and



As plants bacame more efficient at gathering light and conducting water, competition with their neighbors spurred some to achieve great heights. These early tree-like lycopods of the late Devonian and early Carboniferous are (left to right) Cyclostigma, Valmeyerodendron, *and* Lepidosigillaria.

crystallize. The solutions sometimes replace other minerals that originally filled the hollow. The Keokuk geodes, as they are called, range from golfballs to basketballs in size, but are most often about as big as a tennis ball. They are usually lined or entirely filled with clear quartz. The outer layer of the spheroidal mass is generally composed of chalcedony, a hard, chert-like silica mineral that resists weathering; hence the geode is left behind as its limestone casing dissolves away.

Following the erosional phase in the late Devonian and early Mississippian, the land surface of the Ozark region remained somewhat island-like and very near sea level. On the swampy soils and sandy banks of these tropical islands, vascular plants were pushing back the limits of size and complexity. Still without true roots as we know them, *Valmeyerodendron* had reached nearly a yard in height, while *Cyclostigma* and *Lepidosigillaria* had climbed to 25 feet or so with trunks a foot in diameter. All had tiny, scale-like leaves, very much like modern clubmosses. The first groves of tree-sized plants, if not actual trees - what botanists call **arborescent growth** - had developed in the Ozarks, shading lower-growing, more primitive vascular plants, mosses, and liverworts.

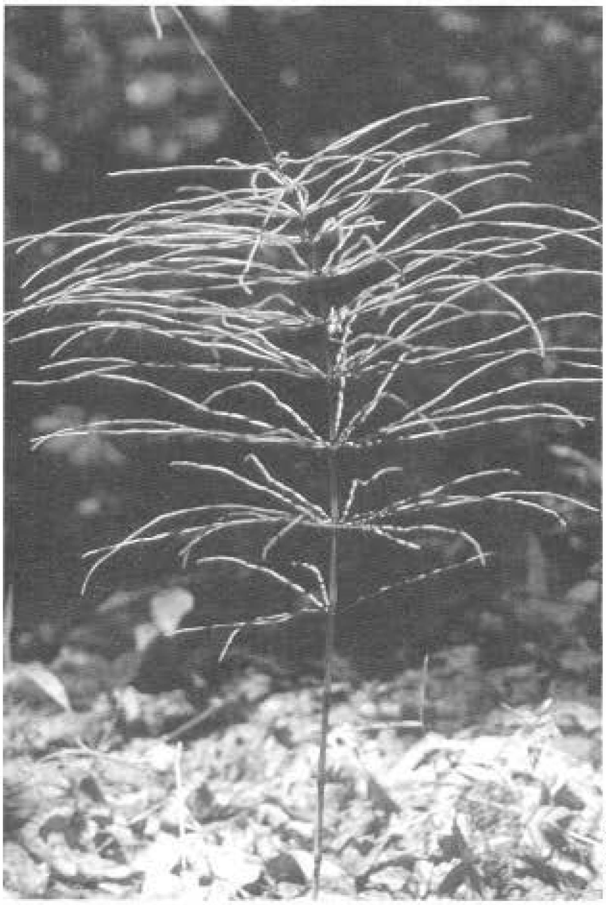
Rare in Missouri, today's clubmosses are all small in stature, but their ancestors grew to over 100 feet.

Jon Hawker

Mississippian amphibians were making similar evolutionary leaps, and the fossil record seems to explode with a dozen new families and many genera. Some were large and alligator-like, both in shape and in lifestyle. These may have lounged on the muddy banks of rivers and lakes, snapping at their careless relatives and at passing fish. Smaller species might have climbed plants chasing cockroaches and dragonflies; others were entirely aquatic. Intermediate forms fed on the smaller, and fell prey to the larger. A few, called aïstopods (= "unseen feet"), were remarkably snake- or eel-like, with tiny legs, or none at all. If not aquatic, these mysterious amphibians probably slithered through marshes like sirens or slipped through the dense vegetation and fallen debris onshore in a manner similar to modern caecilians. If the fossil record can be believed, there were as yet no frogs, toads, or modern-looking salamanders.

By the end of the Mississippian, the ocean had been pushed back once again and all of Missouri was above sea level, although never by more than several hundred feet. Shallow seas covered northern Missouri off and on for the next 40 million years, a time referred to as the Pennsylvanian Period. These shallow seas periodically recreated the original island character of the Ozarks. During the late Paleozoic, great forests developed over much of the continent, including the Ozark Islands, but still without a single recognizable species of tree. Swampy lowlands were now filled with strange plants known collectively as lycopsids, a group of giant clubmoss relatives that could form an airy canopy 100 to 150 feet overhead.

Predominant among these "lost continent"-style forests were three genera of treelike lycopsids, or clubmosses: *Lepidodendron, Lepidophloios,* and *Sigillaria. Lepidodendron* and *Lepidophloios* were both scaly-leaved and much-branched, reminiscent of a clubmoss on steroids, while Sigillaria looked more palm-like, similar to modern Australian grass-trees. Other enormous canopy species, in the genus *Cordaites,* bore strap-shaped leaves over 3 feet long that spiralled up the trunk like a modern *Pandanus.* Now entirely extinct, *Cordaites* and its relatives represent one of the earliest plant groups to bear seeds and are generally considered to be ancestral to the conifers.


Jon Hawker

Like ancient clubmosses, the ancestors of today's horsetails were also giants.

Like groves of giant bamboo, a huge kind of horsetail called *Calamites,* mixed with many kinds of tall tree ferns, created a dense understory layer beneath the high canopy. Carpeted by bunches of moss, spreading fingers of liverwort, and masses of coarse and dainty ferns, horsetails, and quillworts, a tropical Pennsylvanian swamp looked like something from another planet. One unique group of shorter plants was *Sphenophyllum,* now extinct, a slender, trailing plant several yards long that apparently scrambled up into the branches and leaves of its taller companions. So lush and wet were these unusual forests that decomposing fungi and bacteria could not keep up with the crush of accumulating organic matter as the plants died.

As generations of giant clubmosses, horsetails, and their shorter cohorts lived and died, a vast layer of partially decayed trunks, stems, and leaves built up in the sodden ground and soggy marshes and swamps that separated the high ground of the Ozarks from the sea. Just as wet oak leaves stain fresh concrete, tannins and other organic materials released by the dead vegetation turned the water acidic and the color of strong tea. Preserved by high acidity and lack of air, decomposition of the dead and fallen was largely arrested. Later, mud, sand, and other sediment would cover the lot, sealing them for hundreds of millions of years. The mushy deposits were then compressed by the weight of the sedimentary rock layers collecting above and hardened into **coal**, a rock composed of almost pure carbon.

Jerry D. Vineyard

Missouri, so often called the Cave State, has undergone several episodes of cave-making, that produced the more than 5,000 caves known today. Cave Spring on the Current River, here shown from the spring looking out through the cave entrance, originated in an earlier erosion cycle.

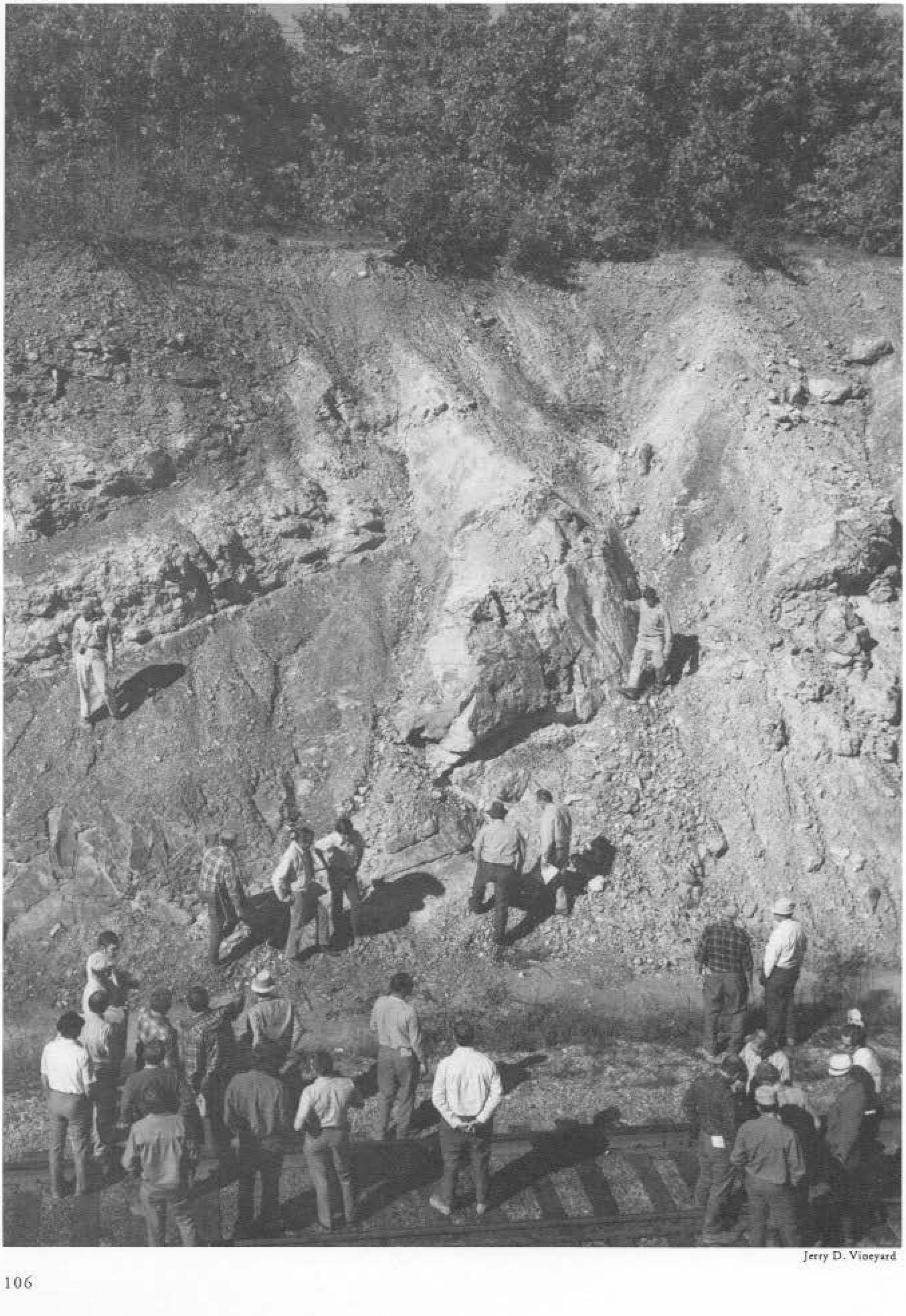
Early on, geologists lent this material's name, carbon, to the Carboniferous Period, that great span of time between the end of the Devonian Period and the closing period of the Paleozoic, the Permian. More recently, based on fundamental differences in sediments and fossils, the Carboniferous has been more logically divided into two smaller periods; the Mississippian and Pennsylvanian. Widely dispersed in northern and western Missouri, and across the river in Illinois, the sedimentary layers associated with Pennsylvanian coal deposits yield abundant casts and impressions of the bizarre plants and animals of the day, important clues to our Carboniferous landscape. Outside Missouri, Carboniferous deposits underlie roughly 13 percent of the North American continent, distributed among 36 states; coal is mined in 24 of these.

During the Pennsylvanian, crocodile-sized amphibians still swam and slithered through the swamps, while smaller versions climbed into the peculiar lycopsid "trees." The earliest forms that can be linked with reptiles, the first animals to lay shelled eggs on land, competed for food and space on the forest floor with their more primitive amphibian companions. Most of these animals were predatory and were carefully watched from above by foot-long dragonflies and a host of other smaller flying insects. Cockroaches and a growing variety of crawling insects, including the first beetles and true bugs, wandered the lush forest floors. Some fell prey to giant centipede-like creatures called arthropleurids. A growing number of insects were becoming increasingly specialized for feeding on particular members of the expanding community of giant clubmosses; in turn these insects fed ever more specialized predators. In fact, some of these Carboniferous insects must have become so highly specialized for feeding on giant clubmosses, or were so well matched to the unique lycopsid environment that at the end of the Paleozoic more than a half-dozen unlucky orders passed into extinction and did not survive the rise of dinosaurs and seed plants.

During most of the Pennsylvanian Period, many portions of the older Mississippian limestones and dolomites underlying the Ozarks were slowly dissolved and undermined by brown, acid swampwaters that dribbled down through the rocks. Brewed from heavy accumulations of organic matter, the percolating tannic acid in the swampwater dissolved into the carbonate rock and created an expanding system of caves. At the surface, thousands of sinkholes appeared as the overlying rocks weakened and cave roofs collapsed. Because all were at or very nearly at sea level, the accumulating water could not escape and the sinkholes filled with water and mud as fast as they formed. Swamp and marsh plants made themselves right at home, as did all of the aquatic and semi-aquatic animals of the day. The Missouri landscape probably looked very much like the Florida Everglades, although obviously populated by an entirely different mix of creatures.

These Pennsylvanian sinkholes slowly filled with clay and other sediments, including organic matter, and, during the next few million years, were buried under new layers of rock. After hundreds of millions of years of erosion, many of these "filled sinks" were again exposed. During their millions of years of filling, burial, and erosion, very pure forms of clay accumulated in some sinks, coal formed in others, and a variety of iron minerals, such as pyrite and hematite, crystallized in still others. These Pennsylvanian filled-sink deposits were among Missouri's first and most valuable sources of clay and iron as 18th and 19th century mining and manufacturing got underway in the Ozarks. Similar sinkholes and filled sink deposits had also been generated on the Cambrian surface millions of years earlier, and these truly ancient filled sinks may sometimes be seen in roadcuts.

Most of what we know about Carboniferous plants and animals comes from swamp deposits because that is where materials accumulated most easily and where fossilization is most likely to occur. However, we must not be led to believe that all land was swampy or that all Carboniferous forests were identical. On the gently rolling Ozark hillsides surrounding riverside and coastal swamps, for example, a totally different set of living conditions generated a very



Jerry D. Vineyard

Geologists on a field trip study a filled sink, exposed to view in a railorad cut near Rolla. Some sinks that were part of ancient karst landscapes were filled with high-grade clays and/or iron minerals, that can be mined.

different type of forest. Less humid and better drained, these slightly elevated hillsides could not support the water-loving lycopsids described above. Instead, these sites were dominated by several kinds of enormous seed ferns, including *Lacoea* and *Palaeopteridium*, similar to those that can be seen at the Missouri Botanical Garden Climatron. Forming a low canopy with the tree ferns were two other kinds of tree-sized plants, *Megalopteris* and *Lesleya*, both unique and also now extinct. These last two sported long, slender leaves that divided occasionally into separate lobes with serrated edges. Unfortunately, nothing similar to *Megalopteris* or *Lesleya* exist today for the sake of comparison. Like the canopy, the understory of this upland forest also had its own distinctive shorter species, all of which were closely related to those found in lower, wetland environments.

Not once during the Pennsylvanian was the boundary between land and sea ever firmly established in Missouri. For 30 million years, the land and sea swapped control over the disputed territory numerous times, an unstable situation that fostered the cyclical development of lush swampy forests and shallow coastlines, and eventually produced America's priceless coal deposits. There are a number of plausible explanations for the periodic dominance of either the terrestrial or the marine habitat.

One theory suggests that sea level rose and fell in response to massive southern hemisphere glaciers that were on the move during the Pennsylvanian. There were in fact major Carboniferous glaciations on Gondwana as it drifted toward the South Polar, and we know that Ice Age glaciations in the Northern Hemisphere caused similar sea level fluctuations world-wide. Another idea proposes that the ocean floor itself was undergoing elevation movements - a result of continental drift - which were then reflected in rising and falling sea levels. A third proposal allows the land itself to rise and fall. Another suggestion relies on a more simple modern counterpart that we are actually able to observe and measure.

As a Pennsylvanian forest developed, a layer of organic matter accumulated that would ultimately be converted to coal. As it matured, each forest also collected silt and other sediments from periodic flooding. Both processes allowed the swamp to slowly creep out into the saltwater domain. Whenever silt deposition was limited or stopped entirely, however, the balance would shift, gradually causing the land to sink or subside. This would happen whenever rainfall or erosion upstream was curtailed for some reason.

Today, a similar process occurs along the Gulf Coast of Louisiana. At a rate of several feet each decade, coastal freshwater cypress swamps are inundated and killed by saltwater as they slowly sink beneath sea level. The subsidence seems to be a direct result of lowered sedimentation rates by the rivers that discharge into the Gulf, especially the Mississippi. Major dams built on the Missouri River in the 1940's and 50's have removed roughly half of the Mississippi mud that once kept delta bayous marching into the sea. Without the mud, the seaward march stops. As a result, Louisiana no longer grows southward into the Gulf as it once did. Today, the Gulf is reclaiming territory it lost centuries earlier and Louisiana loses land instead of gaining territory.

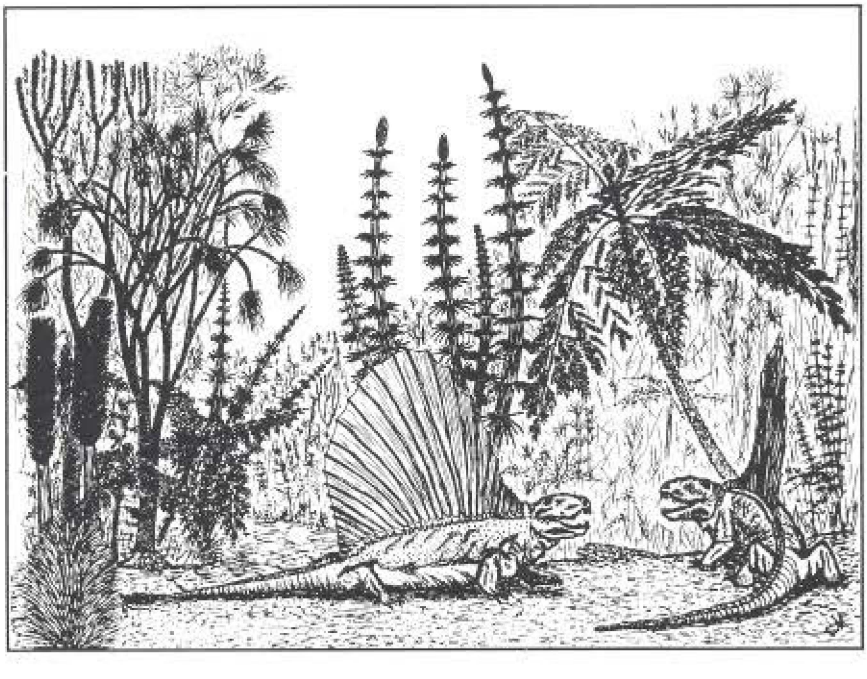
Whatever the cause, the succession of Pennsylvanian rock layers records at least 50 cycles of alternation between fresh- and seawater. Each sedimentary cycle, or **cyclothem**, is similar in characteristics. First a layer of silty sandstone was laid down by fairly swift coastal rivers, followed by a fine-grained sandy shale as the delta built and the flow of water slowed. The change from sand to silt marked the complete ousting of saltwater from the marine environment. Now freshwater, the muds that formed this shale provided support for a developing forest of *Lepidodendron* and *Sigillaria*. Their fossilized root stocks, called *Stigmaria*, are generally found only in this layer of shale. Above the shale, a layer of coal suggests the accumulation of organic matter on the forest floor. Then, and very distinctly, marine shales, then silty limestones, and finally pure limestones cover the remains of the swamp. The clear line between marine and freshwater fossils indicates that the land subsided - or the water rose - quite suddenly and that the forest plants were quickly killed by the influx of saltwater. Now, once again, deposition of sand by coastal rivers re-initiated the process of encroachment into the sea.

As these cycles of change took place on Pennsylvanian surfaces all over the world, several biological revolutions occurred in the seas. Crinoids and trilobites were about to be toppled from their long-held places of dominance. The last of the ancient armored fishes vanished from the earth and the first modern marine bony fish appeared. Today, their descendants dominate virtually all aquatic environments. Despite the rise of bony fish, sharks became a common feature during the Pennsylvanian; cartilage-supported fish were still vital competitors and expanding their horizons rapidly. In fact, monsters larger and more impressive than "Jaws" would not appear for another 250 million years.

The End Of An Era

The Ozark hills were all above water during the Pennsylvanian, but only just barely. Probably no more than 400 feet separated the highest, driest St. Francois knob from the fluctuating tidal marshes and swamps that ringed the tropical island. However, for the next 50 million years or so, during the Permian Period, the Ozarks would rise several thousand feet and its sediments and rocks would once again be subjected to intense erosion. The shallow seas that had periodically washed over the continent withdrew with the rise in elevation. Some of the uplift was undoubtedly associated with the crunching together of the great Pangaean supercontinent which began at the end of the Permian. Virtually all Permian marine invertebrate fossils disappear at this time, indicating widespread effects in the deep oceans as well as on land. Because of the erosion, we have little fossil evidence today to tell us what was actually going on around the Ozarks. Once again, fortunately, we can piece together some of the puzzle from fossils gathered elsewhere.

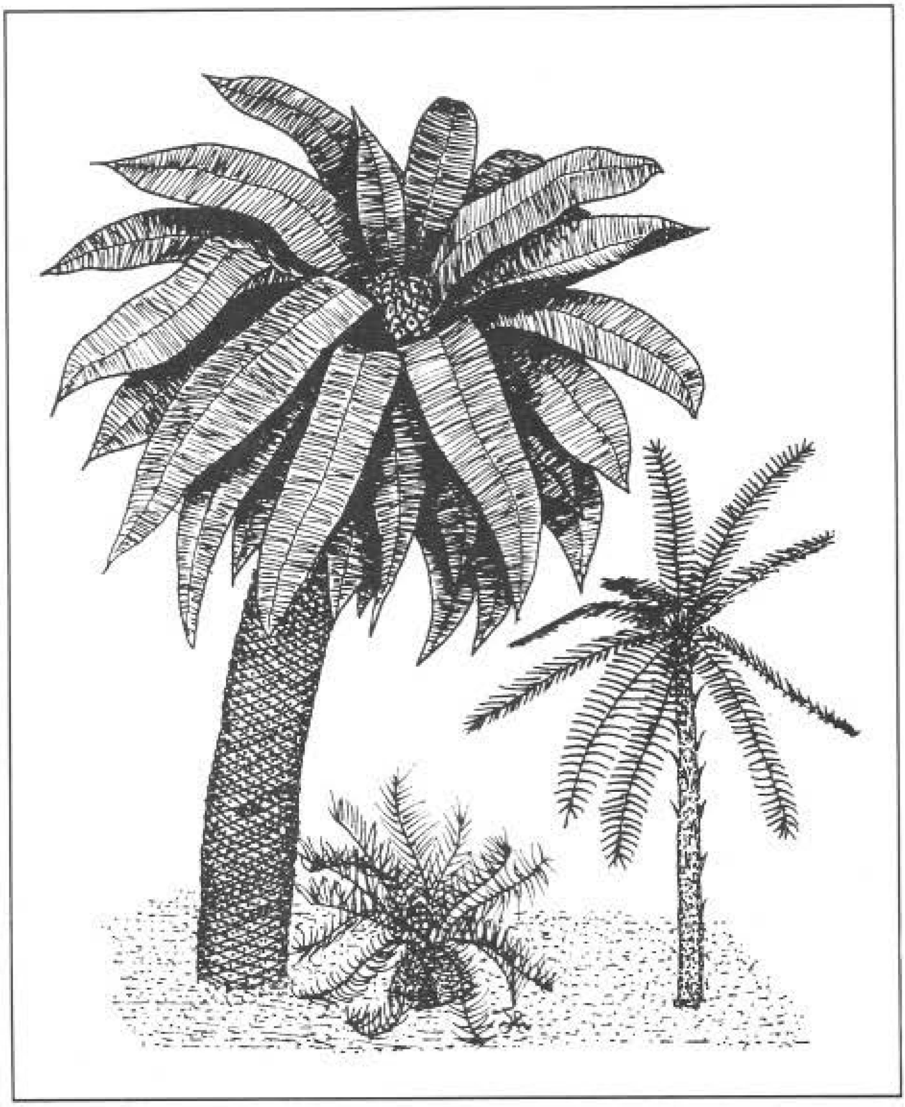
On the banks of a late Carboniferous stream shrouded by a forest of tree ferns and giant fern relatives, a Dimetrodon *attempts to intimidate an intruder with its high dorsal fin. The hairy plant in the left foreground and the two immediately behind on the opposite bank are clubmoss relatives called* Sigillaria. *Two other clubmoss kin on the other shore include the droopy, tree-like* Lepidophloios, *and the fuzzy, upright* Lepidodendron. *A giant horsetail relative called* Calamites *stands directly behind the center* Dimetrodon, *flanked by a tree fern.*



During the Permian, early dinosaur-like and mammal-like reptiles wandered the continents of the earth among some truly monstrous amphibians, such as the 6-foot Euryops, another alligator-like predator. There were also a variety of smaller amphibian species, including the first tailed "frogs." Most swamp-dwelling amphibians and reptiles, such as the fin-backed Edaphosaurus, a mollusk-eater; Dimetrodon, a toothy predator; and the most primitive turtle-like reptiles in the fossil record were forced to withdraw from Missouri as the land drained. In fact, following this exodus of freshwater animals, most aquatic and semi-aquatic reptiles and amphibians probably lived no closer than 100 miles to the west, in the swampy terrain that bordered shallow seas covering Texas, Oklahoma, Kansas, and Nebraska. Some Ozarkian species could have survived in riverside environments, but most animals in Permian Missouri would have had to adapt to the drier forests on well-drained hillsides. The forests themselves were changing; Carboniferous spore-bearing plants were yielding to more efficient seed-producers.

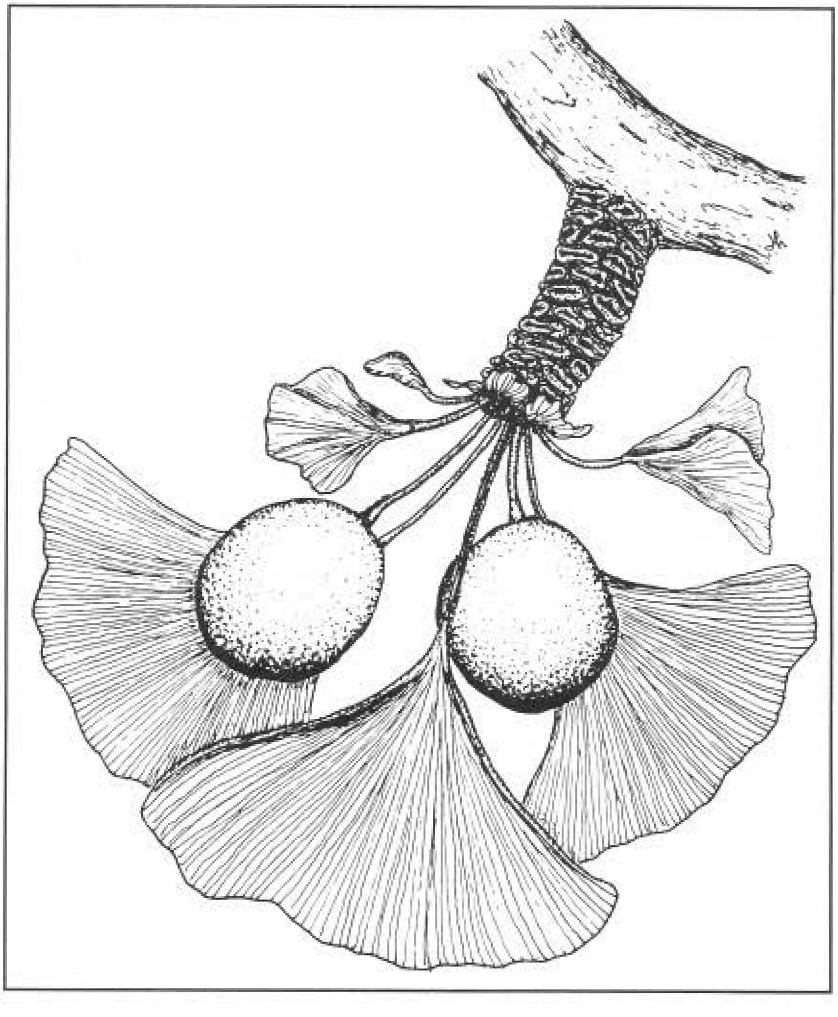
On those parts of Pangaea that would soon become Gondwana - today's modern continents of South America, Australia, and so on - proximity to the South Pole at the end of the Carboniferous created a dramatic period of climatic stress. The luxuriant giant clubmoss swamps typical of North America declined rapidly and were replaced by an impoverished, even more primitive flora dominated by seed ferns. Most of these ferns died out at the end of the Pennsylvanian. Their loss was hardly noticed, however, because warming of southern lands in the Permian allowed the spread of more advanced seed plants that had continued to develop on the northern, more tropical parts of the supercontinent. These innovations included newer forms of *Cordaites* that have no modern counterparts, plus others that might be vaguely familiar to us even today. The first fossils that are clearly primitive cycads and *Ginkgo*, for instance, are found in Permian strata.

Many kinds of palm- and fern-like cycads graced Missouri forests in the late Paleozoic and Mesozoic.



Cycads are related to conifers, such as pine and spruce, but look more like small, dark green palms or coarse ferns. The more attractive kinds, such as *Cycas*, are often grown indoors for decoration. Modern cycads are few in number and restricted to tropical and subtropical regions. During the Age of Dinosaurs, however, they and their close relatives became a dominant element of our flora with a much greater variety of leaf and stem shapes and sizes.

The modern genus *Ginkgo* has but a single species, a once-rare "living fossil" called the maidenhair tree. *Ginkgo* survived into the present in a remote area of southeastern China, only discovered in 1956, and in a few well-tended temple gardens. Descendants of those carefully nurtured trees with their unique, fan-shaped leaves have now been widely planted all over the globe. Like cycads, *Ginkgo's* ancestors arose in the Carboniferous, but became most important in the time of the dinosaurs. Many other kinds of seed-bearing plants appeared in the Permian forest and would gradually replace all but the most persistent ferns and fern allies.



The ginkgo, commonly planted in Missouri's city parks, once provided shade for dinosaurs throughout Laurasia, but is now native only to China.

With the Permian uplift, the greatest era of sediment accumulation and rock formation in Missouri - the Paleozoic Era - had come to an end. For the next 200 million years, the highest and most recent strata of this era would be stripped away by wind and rain. In the central Ozarks, erosion would again expose most of the St. Francois mountaintops. By 225 million years ago, the dawning of the Mesozoic Era, the period of "middle life" dominated by dinosaurs, almost all of Missouri was well above sea level and well drained.

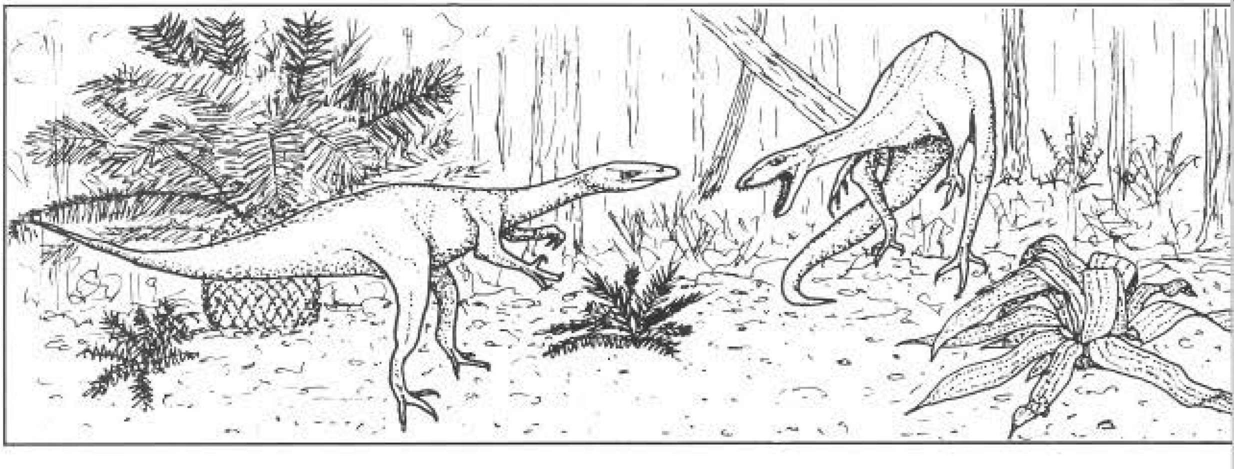
The seas of the Paleozoic Era deposited nearly all of the rocks that underlie the modern surface of Missouri. Uplift and erosional cycles tore down older igneous and sedimentary rocks - sandstones, shales, limestones, and dolomites - while depositing new layers on top. The erosion of the older layers left the surface strewn with tons of chert fragments that had formed within the Paleozoic sediments. Much of the Ozarks was above sea level during the last 200 million years of Paleozoic time and offered living space to the first land plants and animals. By the end of the Paleozoic, reptiles and amphibians crawled through Ozark forests of giant fern relatives and the first seed-bearing plants.

The Mesozoic - The Age Of Dinosaurs

The separate land masses that had existed during the Paleozoic began to drift together late in the **Permian** and fused as Pangaea for a brief period in the **Triassic**. No sooner had this great supercontinent been thrust together early than it began to rift apart once again. As described earlier, this separation allowed the ancestors of most terrestrial plants and animals to follow independent evolutionary paths on the northern Laurasian and southern Gondwana supercontinents for over 100 million years. Some of this independent evolution had preceded the actual breakup.

During the Permian a unique group of plants called **glossopterids** (= "tongue-ferns," in reference to their characteristic leaf shape) had developed on the southern continents. Fossils of these small woody plants, members of the genus *Glossopteris*, appear most commonly with extinct forms of primitive ferns and fern allies, all holdovers from Gondawana's cold, swampy **Carboniferous Period** when they dominated the flora. The build-up of organic matter in these swamps in the Permian, now dominated by *Glossopteris*, eventually contributed valuable coal deposits to the modern Australian economy, just as Pennsylvanian swamps provided coal to North America.

Glossopterids became rare in the floras of Gondwana during the early **Mesozoic**, and disappeared entirely by the end of the Triassic. However, a number of interesting Mesozoic family lines seem to have descended from these short-lived and enigmatic seed plants, some of which may still be around today. The "tongue-ferns" are unique among fossil plants of the period in that they protected their seeds in modified leaves. This unusual trait places them in a good position to be ancestral to the flowering plants, or **angiosperms**, all of which protect their seeds in tissue derived from modified leaves, and now referred to as the "ovary." Although Glossopterids never appeared among the plants of North America, and so were never a part of Missouri's forests, their presumed descendants now dominate the modern world's vegetative communities.

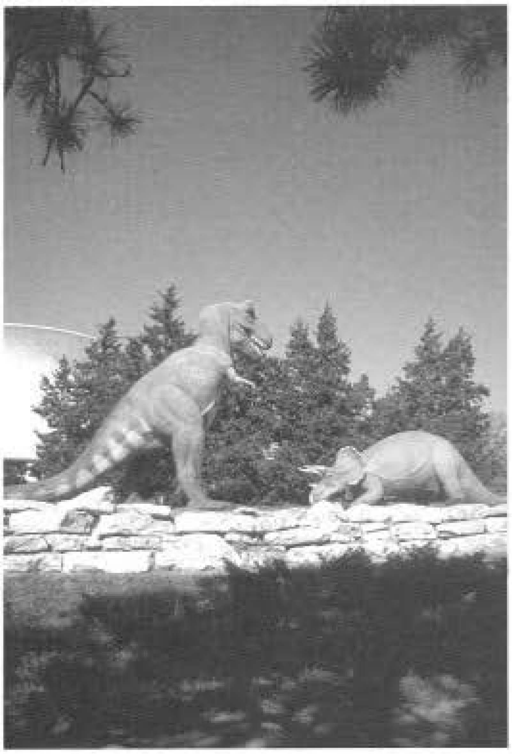


In a Triassic Ozark forest of conifers and cycads, two small, bird-like theropods dispute an important point of dinosaur etiquette.

Nearly all of the soils and sediments that formed in Missouri during the Permian and Mesozoic have been worn away, leaving practically no fossil evidence of this enormous span of time. The uplift that resulted in the loss of all this material, a vertical rise of the Ozark upland of over 1,000 feet, would not commence until midway in the **Tertiary Period**, long after the dinosaurs had all passed into extinction. Meanwhile the Ozarks and surrounding countryside must have been occupied by the same diversifying life forms that lived in the rest of Pangaea and Laurasia, for which we do have much fossil evidence. It seems reasonable to assume, therefore, that Triassic Missouri was home to a great many dinosaurs. At the time, these beasts constituted only a slender minority amongst a much wider array of amphibians and primitive reptiles. But their time was not far off.

There were many sizes and kinds of dinosaurs, not all huge, and not all closely related. The term "dinosaur" does not fit any of our usual taxonomic categories, such as family, order, or class; the term is usually applied to one or more orders of reptiles. The name itself means "terrible lizard," but dinosaurs were NOT lizards; lizard-like reptiles were around for tens of millions of years before dinosaurs, and they're around still, largely unchanged. Collared and frilled lizards notwithstanding, lizards typically crawl about. Dinosaurs got up and ran, and some big ones ran very fast indeed. No, dinosaurs are more closely related to crocodilians, if they are closely related to any modern reptile. Based on a number of anatomical similarities, dinosaurs may in fact be most closely related to birds. They are so much like birds, they may actually have been birds. Paleontologists are trying to decipher clues that have led a number of them to conclude that some dinosaurs at least were warm-blooded, cared for their young, lived in organized societies, and may still be around today as birds. Others disagree. The problem of who the dinosaurs were and how they lived will certainly not be resolved in this book. It hardly matters in terms of the Mesozoic Missouri landscape.

Missouri's Triassic dinosaurs could be assigned to either of two major groups. Both groups began as upright animals, one bird-hipped and plant-eating, called **ornithischians**, the other lizard-hipped and mainly plant-eating, referred to as **saurischians.** Later in the Mesozoic,



Jon Hawker

Tyrannosaurus *once scowled across the land that is now Missouri, preying on* Triceratops. *Life-size models can be seen at the St. Louis Science Center.*

the lizard-hipped dinosaurs evolved into two other groups, the theropods or "beast-footed" reptiles, such as *Tyrannosaurus*, whose ferocious visage scowls across Forest Park at the St. Louis Science Center, and the larger, four-legged **sauropods**, or "lizard-footed" reptiles, such as that paradigm of dinosaurness, *Brontosaurus*, the all-too-familiar oil company symbol.

The bird-hipped dinosaurs of the Triassic would later diversify into four groups - the **ceratopsians** (= "horned dinosaurs"), like *Triceratops*, forever defending itself from the aforementioned *Tyrannosaurus* model in museum dioramas around the world; the **stegosaurs** (= "covered lizards"), such as *Stegosaurus*with its impressive array of bony plates; the **ornithopods** (= "bird-foots"), including the duck-billed dinosaurs; and the tank-like armored **ankylosaurs** (= "crooked lizards"). Some Triassic sauropod dinosaurs, like *Yaleosaurus*, fed on all fours, but most bounded or walked on two legs.

Cycads, cycadeoids (cycad relatives), and conifers, or **gymnosperms** (= "naked seed"), were on the rise in the Triassic, as were a wide range of broad-leaved seed plants. The growing spectrum of heights and foliage types among seed-bearing plants increased the range of food choices for dinosaurs, allowing extremely rapid diversification. As the dinosaurs competed and changed, taking advantage of the wide choice of foods, they eventually came to range in size from a large lizard to the most gigantic land animal to have ever trod the earth. But size is only one characteristic by which we can describe and distinguish the members of a group of animals. Then as now, animal life may be conveniently divided into three main groups based on diet. The most abundant animals in a natural system are the plant-eaters, first in line to tap the solar energy trapped by plants during photosynthesis. This was also true of dinosaurs. While most dinosaurs were placid vegetarians, or **herbivores**, some of the most famous dinosaurs were quick and agile meat-eating predators, or **carnivores**. Finally, like many familiar animals today - raccoons, opossums, skunks, bears, and so on - a few dinosaurs were **omnivores** that dined on a little of either fare.

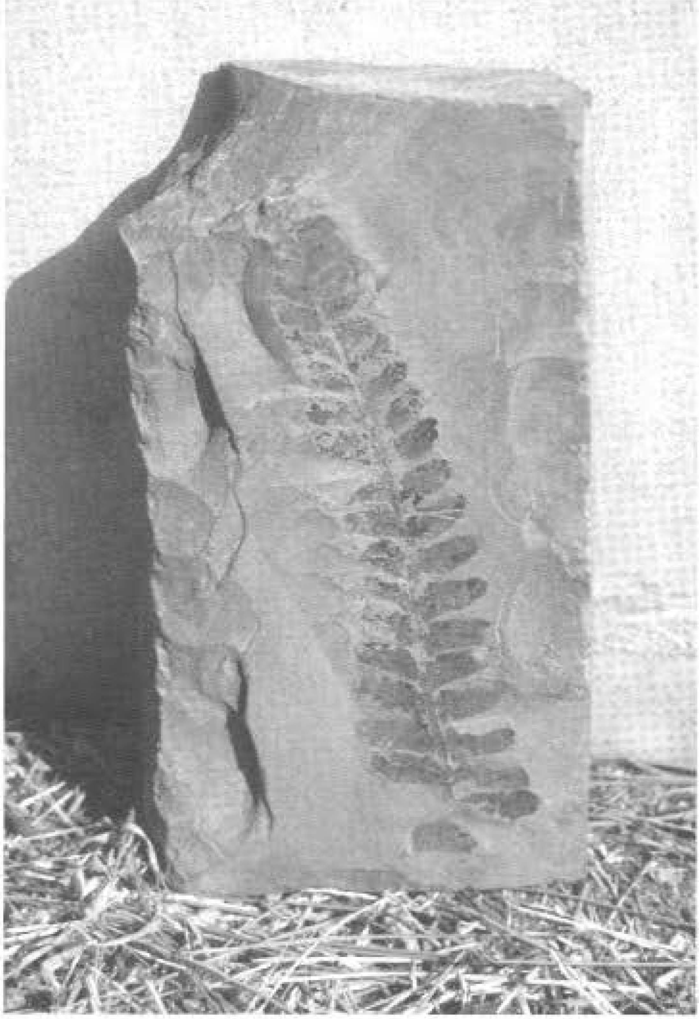
As with size and diet, it is also likely that the same range of social behaviors that can be seen in modern mammals existed among dinosaurs. Just as the members of a herd of wildebeest on an African plain benefit from the proximity of their fellows, some herbivorous dinosaurs also took advantage of the attributes of living in a group, such as increased protection and reproductive efficiency. Other species may have wandered in small family groups, or were loners. Large predators were often loners, but small hunters might have prowled in packs. When we think of dinosaurs, we automatically focus on land animals, but let us not forget Ozark waterways.

Reminiscent of the crocodiles along the Nile, enormous phytosaurs roamed the banks of Missouri streams, ambushing turtles, amphibians, and smaller dinosaurs that strayed too close. Phytosaurs may also have gorged themselves on bony lungfish, lobe-finned fish related to the ancient and mysterious coelacanth, or primitive ray-finned fish ancestral to the bowfin, gars, paddlefish, and sturgeon of today. By today's standards, many of the turtles that swam in Ozark rivers and sinkholes were rather ordinary-looking, but on land there were heavy-bodied tortoises like those of the Galapagos and Aldabra Islands stumbling through the underbrush.

As mentioned, Triassic Ozark hillsides were forested by a mix of palm-like cycads and cycadeoids; ginkgos, araucarian "pines" (also perhaps familiar to some as potted plants) and other kinds of cone-bearing seed plants; and more advanced seed-bearers ancestral to flowering plants, possibly of *Glossopteris* or seed fern lineage. Among these latter plants were the broad-leaved caytonias and peltasperms, groups whose fossils appear only in Mesozoic rock formations. At first, these advancing seed plants were restricted to the best soils in the mildest tropical climates, where it was always summertime and the living was easy. Only later would seed plants be able to expand their horizons to include habitats where special restrictions applied and a variety of adaptations were necessary for survival.

During most of the Mesozoic, masses of horsetails and other fern allies still formed much of the understory in forests, crowded the banks of streams and marshes, and crept over bare rock surfaces. A few lush swamps supported scattered remnants of the Carboniferous flora, including *Calamites*. On the choicest sites, however, the more efficient seed plants rudely shoved these remnant spore-bearers aside in their rush toward preeminence.

Remarkable plant fossils such as this fern-like frond are sometimes found in fine-grained rocks that once were muddy lake bottoms, now become shale, siltstone, or mudstone.



Susan C. Dunn

The Age Of The Thunder Lizards

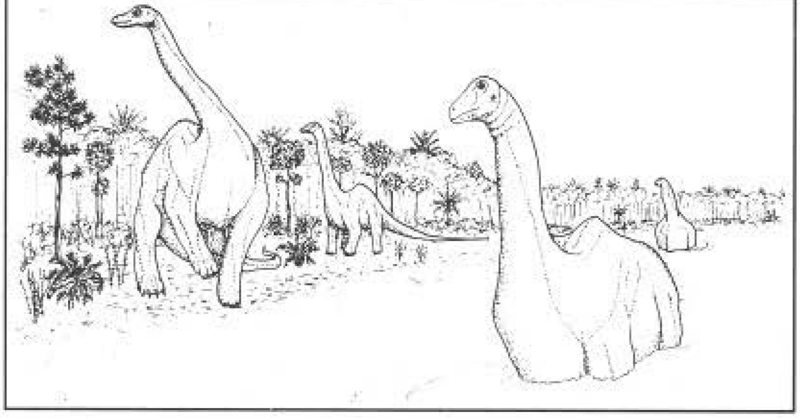
The early lines of dinosaurs diverged late in the Triassic. Within 10 or 20 million years, during the **Jurassic Period**, the truly great "thunder lizards" first appeared, all descendants of the first sauropods. The long-necked *Brontosaurus* (now often referred to in correct zoological jargon as *Apatosaurus*), the larger *Brachiosaurus*, and their equally massive cousin, *Diplodocus*, stalked the Missouri countryside. These were among the largest land animals that have ever lived, incredible plant-eaters over 60 feet long. Some, such as *Brontosaurus* and *Diplodocus*, it seems, were even capable of standing on their hind feet to reach tender growth high in the trees. They and their kin slogged through streamside marshes and swamps, and plodded through forests. To sustain their immense bulk, they scooped up bucketsful of plants from the water, or ripped off whole branches from trees - leaves, twigs, and all. One has only to watch African elephants tear down and rip apart an acacia to appreciate the destruction these great dinosaurs must have caused as they filled their enormous bellies.

The upright *Camptosaurus* and armored *Stegosaurus*, which may also have fed on tall plants by rearing up on its hind feet like an elephant (a dinosaur forerunner of the ground sloth?), were among the medium-sized plant-eaters in the Ozark forest. Even for such giant predators as the fearsome theropods *Allosaurus* or *Ceratosaurus*, one of these giant beasts must have provided more than enough food. Unquestionably, a horde of smaller reptilian and insect scavengers also participated in the clean-up. Grotesque animals ancestral to the first true mammals may have sneaked a few mouthsful of rotting meat when the great carnosaurs weren't looking. With no shortage of large predators, these ancestors of shrews and 'possums would have had to have been very careful indeed. Although mammals were around during most of the Mesozoic, they were not as yet competitive ecologically and stayed in the background. Most probably they fed only at night, or from the cover of dense vegetation.

With their great height and reach - up to 40 or 50 feet - the largest of the Jurassic dinosaurs must have strained the abilities of primitive conifers and cycads (known by horticulturists to be depressingly slow-growing under the best of conditions) to replace their lost portions. This feeding pressure may be reflected in the rise of many of the modern conifer families during the Jurassic. All of our modern conifer families arrived in the present following a long evolutionary trail that began with the herbivorous dinosaurs of the Triassic and Jurassic. The trail includes more efficient root and vascular systems, an increase in the use of toxic agents, thorns, and spines to thwart leaf-munchers, more efficient reproduction, and faster growth. Older growth forms simply could not keep up with the feeding pressure. In the Cretaceous, even these modern conifers would be forced out of the mainstream by flowering plants.

Following the Jurassic, shallow seas covered much of North America. During this relatively long period of the Mesozoic, the Cretaceous, open water stretched from the Gulf of Mexico, across southern Texas and eastern Mexico, through Wyoming and Montana, and on into western Canada as far as the Arctic Ocean. Deep layers of debris collected beneath a subtropical arm of the Gulf of Mexico called the Zuni Sea. The Gulf and East Coasts, and the entire Great Plains were underwater. Pterosaurs, such as *Pteranodon*, soared over this sea like enormous albatrosses, while giant turtles, seal-like mosasaurs, porpoise-like ichthyosaurs, and long-necked plesiosaurs fed on fish, squids, and jellyfish in the waters below.

Most of these impressive creatures were not truly dinosaurs in the precise use of the term, but simply large, specialized reptiles of various kinds, no more closely related to dinosaurs than they were to crocodiles. Dinosaurs, four-legged still, remained predominantly terrestrial in the Cretaceous, although their sizes were beginning to conform more to our modern view of the laws of gravity. The biggest, tallest dinosaurs were Jurassic. Cretaceous dinosaurs, while still as large as the largest African wildlife today, were shorter and mostly planted their four feet firmly. An array of duck-billed dinosaurs, ceratopsians, and ankylosaurs now browsed through Ozark forests, chomping the low-growing shrubbery and herbaceous growth. This group of herbivores created a very different kind of feeding pressure on the plant community. Now tall, mature trees were no longer in danger, but their seedlings certainly were. Slow-



Along the margin of a sinkhole pond in the Jurassic Ozarks, nearby movement attracts the attention of two nervous Diplodocus *and a pair of wading* Apatosaurus, *both sauropods and among the largest animals to have ever walked the earth.*

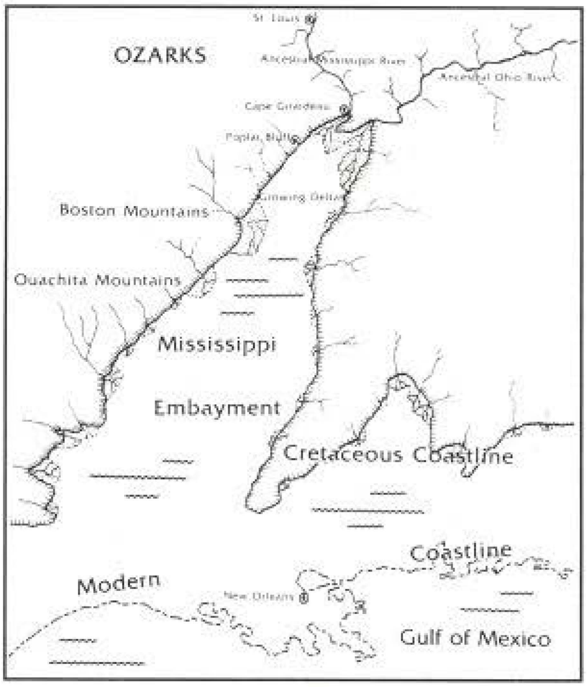
growing plants simply could not maintain much headway in the face of such constant nibbling and chewing. Only the most efficient growers or reproducers - the flowering plants - could withstand the onslaught. And it is in the Cretaceous that this most efficient group of plants literally blossomed.

As the great dinosaurs lived, diversified, and died in and around the great inland sea covering much of the West, the drifting of the continents continued. North America was now on the move as rifting of the great supercontinent Pangaea began. Drifting westward and a little northward, our continent rotated slowly counterclockwise as it traveled. Portions of the North American surface rose and fell slowly in response to the initial breakup. The seas also rose and fell in unexplained rhythms, flooding low lands, then withdrawing periodically.

By this time the southern supercontinent, Gondwana, had already spun off most of its modern daughter continents. South America, Africa, Australia, Antarctica, and India were each nudged slowly toward their modern positions. The north Atlantic, however, was still little more than a rift in the Maker's eye. Seemingly reluctant to part, the two great subdivisions of Laurasia were just coming into position to begin the drawn-out, but inevitable split into Eurasia and North America.

The Beginning Of The Bootheel

The rifting process had great impact locally. Between 100 million and 70 million years ago, a trough some 2,000 to 3,000 feet deep was formed by an extraordinary folding or down-warping in southeastern Missouri. This sunken area would eventually fill with sediment and become the Bootheel region. For the time being, it created a long, slender bay of the Gulf of Mexico, called the **Mississippi Embayment**. With the appearance of this trough ocean waters once again lapped the shores of the Ozarks. Because of all the earthly commotion, the sea alternately crept into the area, then withdrew as



During the Cretaceous, the Mississippi Embayment region of Missouri was created by a downward folding of the crust that allowed an arm of the Gulf of Mexico to extend northward to Cape Girardeau. (Cretaceous coastline as drawn is approximate.)

the land rose and fell. For varying lengths of time, the Gulf of Mexico flooded the mouths of streams draining the southeastern edge of the subtropical Ozark hills. Mud, sand, and gravel carried from the highlands were dumped into the bay along its east and west shorelines, but filled most rapidly at its upper end, where Cape Girardeau and Cairo are today.

The deltas that formed at the mouths of these ancient southeast-flowing Ozark streams led to the creation of vegetation-choked habitats very similar to the present delta of the Mississippi River in Louisiana. Just as during the Pennsylvanian cyclothems, freshwater swamps and marshes were killed each time the Gulf reclaimed land from the advancing shoreline. When the freshwater swamps sank, ocean-going snails, clams, ammonoids, crabs, and fish took over the brackish waters from gar, bowfin, shad, frogs, turtles, and 45-foot crocodiles.

Along the edges of the embayment, and especially at its northern end, growing mud flats permitted shoreline vegetation to establish roots where crabs recently scurried. Because of the feeding pressures alluded to previously, the rapidly developing flora of the Ozarks now included an enormous number of flowering plants, or angiosperms (= "seed in a box," i.e., the ovary). The flowering plants seem to have developed early in the Cretaceous, perhaps as far back as 130 million years ago. By the time of the Mississippi Embayment, 50 to 75 million years later, the group had clearly exploded in numbers of species.

While the murky inshore waters of the embayment supported ancestral bur-reed, lizard-tail, water lilies, and arrowhead, most of the swamp-loving trees were still gymnosperms, such as bald cypress and slash pine; however, a few angiosperms, like the bays and magnolias, had probably already adapted to the water-logged environment. Away from the water, on the sandy or muddy shores where supplying oxygen to roots was not so difficult, flowering plants were clearly wresting control from the conifers and cycads. Palms, willows, cottonwoods, sycamores, and elms, representatives of old groups of flowering plants, sought out much the same habitats they do today.

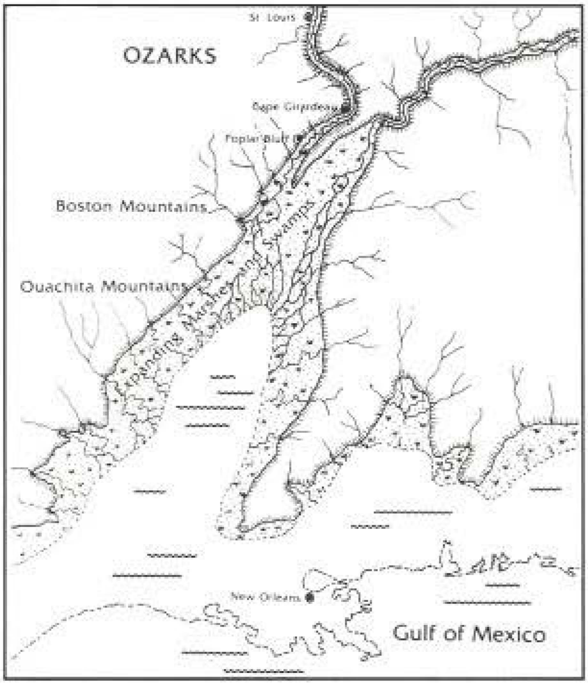
Many of these early flowering plants sought the pollen-carrying favors of insects. They released attractive odors that carried some distance, produced colorful petals as final targets, and enticed with abundant pollen and nectar as rewards for any bug that would visit their flowers. At this stage, flowers such as buttercup, hepatica, and members of the arum family, like Jack-in-the-pulpit, developed a close association with beetles to ensure pollination and seed production. Such plants produce large numbers of stamens and enormous quantities of pollen to seduce the hard-shelled insects. As they tumble and graze over the delectable floral parts, the beetles become coated with uneaten pollen. While the beetles destroy much pollen as they feed, the huge supply ensures that some invariably gets through to the next flower as the ever-hungry insects continue their rounds.

Over the next 30 million years, increasingly complicated relationships between flowers, insects, and other animals - marsupials, bats, and birds - would appear. The close association between an animal and a flower guaranteed the life of each. The animal got fed; the plant got pollinated. Early conifers delivered pollen by using wind currents, in the manner of spores, and conifers remain largely wind-pollinated even today. The ultimate success of flowering plants was due in part to their efficient use of insects, rather than unpredictable air currents, to deliver pollen.

The Cretaceous Ozarks

Up behind the ranks of shoreline vegetation, on the low hills of the Ozarks, a mix of subtropical and temperate species comprised the forests of the day. Tree ferns, cycads, magnolias, figs, moonseed, and breadfruit were sprinkled in with pines, ginkgos, laurels, tuliptrees, oaks, walnuts, and hickories. In fact, most modern plant families were well-established in the region by the end of the Cretaceous, although older groups had obviously not disappeared altogether.

While the vegetation was very modern-looking and would have seemed vaguely familiar were we suddenly plunked in its midst, the animals were still dominated by styles that have obviously become outmoded. During the Cretaceous, the great dinosaurs still ruled the world, radiating into their greatest numbers of species, and into some of their most bizarre forms. The marine species mentioned above hint at the diversity and the degree of specialization reached late in the Age of Dinosaurs. On land, the match between the lifestyles of these



Erosion of the North American highlands gradually filled the Cretaceous trough that had become the Mississippi Embayment region, creating expansive estuarine (mixed fresh- and saltwater) marshes and swamps.

ancient reptiles and their modern mammalian counterparts was even more noticeable.

Like reptilian giraffes, species of duck-billed dinosaurs browsed the forests, nibbling the leaves and stems of shorter trees, shrubs, and herbaceous vegetation. Others, such as *Maiasaura*, made regular forays into the swamps to scoop up algae and rank marsh plants floating at the surface, like moose do today. Ceratopsians, beaked plant eaters with a protective horned frill around their necks, *Triceratops* for example, confined their foraging to the shorter plant life along shore and in forest openings. The upright giants, *Tyrannosaurus, Alamosaurus,* and *Albertosaurus* terrorized these herbivores wherever they wandered. Like turkeys or ostriches, a large number of small and sprightly bird-like dinosaurs pranced about, feeding on whatever suited their fancy: leaves, fruits, seeds, flowers, insects, or other animals. A large number of turtles and frogs, shrew-like mammals, and primitive toothed birds added to the strange Cretaceous mix and also fell prey to these small dinosaurs.

Throughout the 70 million years of Cretaceous time, erosion continued to grind away at the Ozark uplift, eventually wearing it all down to within a few hundred feet of sea level. By the end of the period, there was little difference between the appearance of the shoreline and the land farther into the hills and what we might see in southern Florida today. In fact, nearly all of southern North America, from the Appalachians to the Pacific, supported a similar assemblage of low elevation plants and animals. The granitic hilltops of the St. Francois Mountains, only a few hundred feet above sea level, were now exposed more than they had been for hundreds of millions of years. The igneous knobs were the only sites in Missouri that could offer a truly dry environment in which to live. These continued to harbor Missouri's oldest glade communities.

All across Missouri, swamps and marshes followed lazy, meandering streams from their mouths in the embayment upstream to the center of the Ozarks where their rich, warm waters originated. The same jungle of aquatic plants that lined the banks of the bay and its feeder streams also ringed thousands of water-filled sinkholes that peppered this low coastal plain. In a repeat of another Pennsylvanian process, the acid swamp waters of the Cretaceous dissolved extensive cave systems and sinkholes into the underlying Paleozoic rocks. Except for the cluster of well-drained, forested hills in Precambrian igneous rocks at its southeast corner, the Ozarks took on the same general appearance as the Everglades.

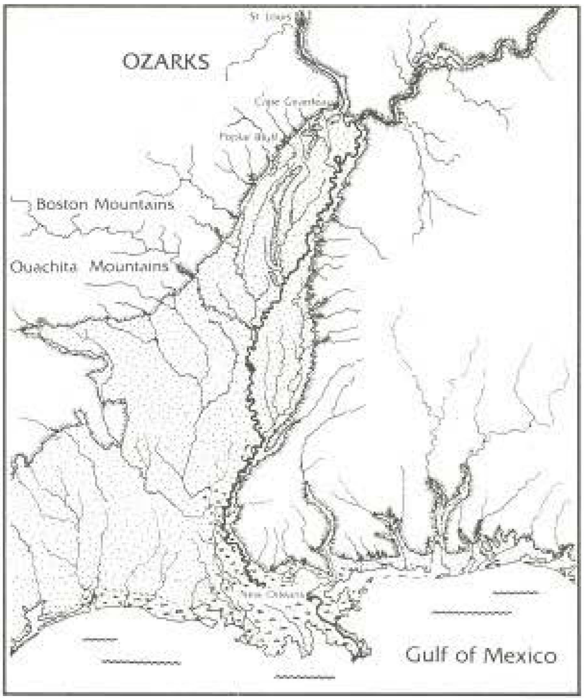
Cretaceous Reminders

Beneath the surface of the modern Bootheel, a fair amount of the sediment that fills the old Mississippi Embayment is Cretaceous in age, deposited by sluggish streams. Although the areas drained by the rivers ancestral to the Mississippi and Ohio were much smaller than at present, the two rivers nevertheless carried tremendous loads of sediment. From the Appalachian uplift to the east, as well as from the Ozarks, they carried enormous quantities of clay, silt, and sand into the shallow bay. The floor of the embayment was raised nearly 600 feet as a result. The Mississippi and Ohio flowed independently at first, separated in the Cretaceous by a finger of lowland in southern Illinois. It is unlikely they joined until tens of millions of years of accumulating delta land finally brought their paths together, probably well outside Missouri's present boundaries, at some southerly point in the shrinking embayment.

Although virtually all evidence of the Age of Dinosaurs in upland Missouri was stripped away with the sediments that contained them, bits of evidence remain in the Bootheel and in a few nearby locations. The alternation of terrestrial and marine life at the northern tip of the old embayment is graphically demonstrated by layers of fossil remains in the sediments of a band of low hills known today as Crowley's Ridge. Now more than a hundred feet above the modern flood plain, and 400 feet above sea level, the sediments of Crowley's Ridge preserve a record of the shifting Cretaceous environments. Where these poorly cemented deposits are exposed by erosion or excavation, they reveal the succession of communities occupying the coastal environment 70 million years ago.

The soft sands, silts, and clays freely give up the impressions of leaves and stems of flowering plants in one layer, and ammonoids (nautilus-like cephalopods), crabs, snails, and clams in another. Although the strata have not yet revealed dinosaur remains, even this limited variety of fossils allows a clear reconstruction of Cretaceous events as described.

Immediately above these easily eroded fossil-bearing layers of Crowley's Ridge sediments lies the boundary between the end of the



The Mississippi Embayment eventually filled with sediment, producing the familiar geography of Louisiana and east Texas, including the "bird foot" delta of the modern Mississippi River. Once thought to be invincibly growing Gulf-ward, the delta is now receding because of large dams on the Missouri River that retard the movement of sediment down-river.

Mesozoic Era and the beginning of the **Cenozoic Era**, the era of "recent life." At the end of the Cretaceous, every kind of dinosaur on the earth - and many other life forms as well - mysteriously vanished. Around the world the boundary between the sediments of the Cretaceous and the first period of the Cenozoic Era, the Tertiary Period, record this well-known, but not yet fully explained extinction of dinosaurs. The best evidence available today implicates a meteoritic impact about 66 million years ago as the culprit, an impact so colossal it had world-wide climatic effects resulting in massive but selective extinctions. The boundary between the layers, commonly called the K-T boundary, for Kreidezeit (= German for "chalk-time") -Tertiary, also reveals something about the extraordinary, but less widely publicized mass extinctions experienced by virtually every group of creatures living on the earth at the time. As elsewhere, the muddy sediments of Crowley's Ridge also mark the momentous changes that occurred at the beginning of what has been called the Age of Mammals.

The Mesozoic also survives elsewhere in Missouri. On an old farm in the Ozarks about 15 miles from Crowley's Ridge, a chance geological event at some point since the Cretaceous has preserved another sample of the muds collecting at this time. At this small site in Bollinger County, activity along an extensive fault system caused an immense block of rock to suddenly drop, producing what geologists call a **graben**, or sunken block. This block took the surface deposits down with it, protecting them from further erosion. Re-exposed by a family digging a well in the spring of 1942, these surface deposits still retain their original character and contents. Trapped in their gray, slimy muds are broken remnants of the lives that occupied the area during the Cretaceous, including a variety of ceratopsian, crocodilian, and duck-bill bones and teeth, and fragments of turtle shell. Included in the sticky muds are the weathered remains of older strata that collected on the Cretaceous surface. Perhaps with further investigation, the muds will reveal more about Missouri life in the Cretaceous.

By the end of the Cretaceous Period, at the close of the Mesozoic Era, much of Missouri had been reduced to a flat, swampy, coastal lowland. Lazy, meandering streams wound across the Ozarks on their way to the shallow Mississippi Embayment, a narrow arm of the Gulf of Mexico. The dinosaurs completely vanished and were soon replaced by mammals and birds. Flowering plants were on the rise and forced ancient plant groups into more hostile environments. Missouri was covered by subtropical to subtemperate forests with familiar kinds of vegetation.

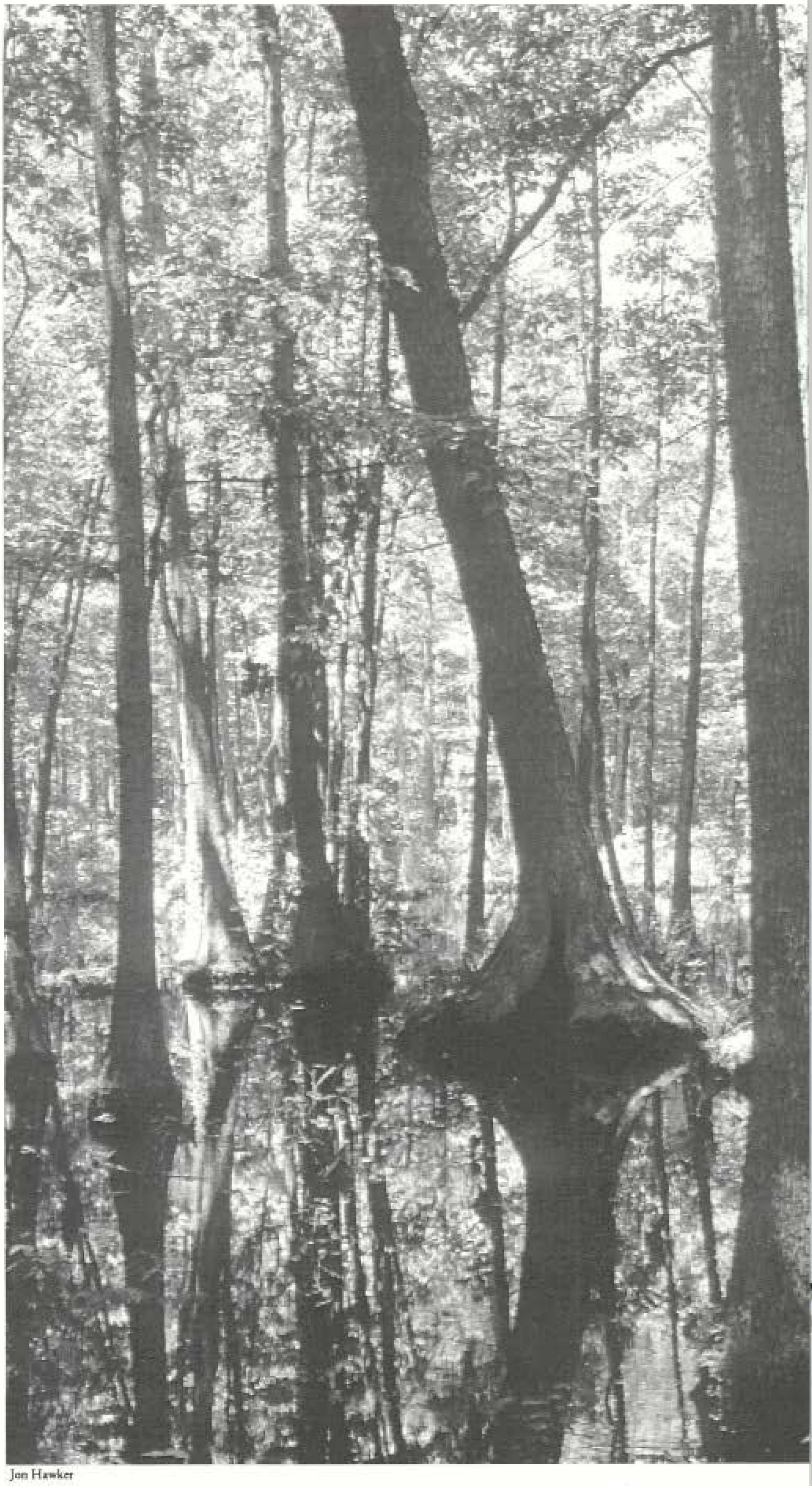
The Cenozoic Era - The Finishing Touches On The Landscape

While some of the sediment currently filling the Mississippi Embayment was deposited during the Cretaceous, most of the debris accumulated during the Cenozoic. This last era, the era of "recent life," is divided into only two periods: the **Tertiary** ("the third") and the **Quaternary** ("the fourth"). These names reflect an older geological time classification system that recognized four major periods in earth history: Primary, Secondary, Tertiary, and Quaternary. The lowest layers of Tertiary deposits in the Mississippi Embayment, laid down in the Paleocene Epoch, 65 to about 54 million years ago, form what are known as the **Midway Group**. These sediments are comprised of greenish, iron-rich, limy sands with abundant fossil clams and snails. These animals reveal the continued presence of a shallow marine environment in the embayment region. This sandy material is overlain by a layer of dense clay with very few fossils, mud that settled out in the quiet backwaters of expanding Mississippi and Ohio river tidal flats.

About 45 million years ago, during the **Eocene Epoch**, Gulf waters had receded far enough to allow freshwater and terrestrial communities to re-establish themselves on the spreading coastal plain. The continent was becoming increasingly temperate as it drifted northwest and dank, murky forests similar to those of the modern Gulf Coast ringed the steadily shrinking embayment. This more temperate Eocene forest, dominated by cypress, slash pine, and tupelo gum, must have spread throughout what were then lowland environments in the Ozarks. The Eocene embayment bayou may have left a few of its representatives around some of the Ozark's sinkhole ponds, such as Cupola Pond near Wilderness and Tupelo Gum Pond in Oregon County.

Jumbled fragments of leaves and stems from these Eocene forests - hickory, sassafras, basswood, and other recognizable species - can be found in the sandy clays of the Wilcox Formation in gullies on the slopes of Crowley's Ridge of Stoddard and Scott counties. The Wilcox was probably deposited in backwaters along terraces and sand bars during floods, where all sorts of debris would have drifted and quietly

The Eocene embayment bayou may have left a few of its representative plant species around some Ozark sinkhole ponds, such as Cupola Pond near Wilderness.



Jon Hawker

settled out. Farther out in the Bootheel, where it is buried more deeply, the Wilcox is an important water-carrying stratum, although its water is quite hard because of an exceptionally high iron content.

As lazily as they meandered through the Ozarks, the streams draining into the bay slowed even more as they entered the broad, flat embayment. From the edge of the Ozarks, they barely crept in the general direction of the retreating sea. The sluggish water tended to stay to the outside edge of the bay, hugging the barely discernible line of Paleozoic rocks at the base of the uplands. In this path, they slowly carved a route that would one day be followed by the young Mississippi, and later, by the St. Francis, Black, and White rivers.

Because of the low elevation difference, the streams draining the Ozarks were only able to transport mud into the bay area for the first 20 or 30 million years of the Tertiary. As the Ozark coastal plain began to rise during its third and final episode of uplifting late in the **Oligocene Epoch**, or early in the **Miocene**, between 30 and 25 million years ago, its streams would begin to flow more swiftly. Following the uplift, large quantities of sand and gravel were swept from the highland and spread across the floor of the embayment. This process accelerated dramatically during the last 15 million years of Tertiary time as the Ozark uplift continued and then finally abated.

The Modern Ozarks - A Tertiary Product

Although subtropical Ozark streams in the Cretaceous initially wandered almost aimlessly across nearly level ground, seeking a path to the sea, they found themselves higher and higher above the Mississippi Embayment as the Tertiary uplift progressed. With their sharply increased gradient, the wide, slow, upstream waters drained more quickly, becoming swift and much more powerful. Cutting down into Paleozoic limestones, dolomites, and sandstones, they tried in vain to reach the same level as the embayment floor. As they cut, they were no longer able to wander and instead became **entrenched** or bounded by bluffs. With these bluff lines our modern Ozark streams preserve the graceful curves of the pre-uplift meanders, now frozen forever as majestic cliffs several hundred feet high.

Ozark bluffs give us a good indication of the volume of water carried by Cretaceous and early Tertiary streams. All rivers and creeks produce meanders whose curves are directly proportional to their stream's width. As width increases, so does the curvature of the meanders. If we look at an Ozark river - the Eleven Point, Jacks Fork, or Current, for example - we see that each river is narrower than the distance between its bluffs. Each of these modern rivers actually wanders about within its ancient bluff lines, looping in much smaller arcs than the bends they carved when they were younger and larger. The modern river does not fit the original channel cut in stone. We see the same kind of "misfit" stream when we look at the Colorado River in Arizona, or the Green River in Utah. Each of these tells us that the ancient stream carried a much greater volume of water than at present. The difference between the heights of the river bluffs in Arizona, Utah, and Missouri is simply a reflection of the heights of the uplifts in the respective regions. The Ozark canyons are not as grand only because the uplift that produced them was a mere fraction of the land's rise in western areas.

In the St. Francois Mountains, the down-cutting water soon intercepted long-buried granites and rhyolites. Sometimes a stream was funnelled into a long-buried valley between ancient Precambrian hills of resistant rocks. However, as some sliced down through the softer Paleozoic rocks that overlay the igneous rocks, their channels wound up directly atop granite knobs, domes, or ridges. Trapped by deepening bluffs of limestone, dolomite, or sandstone, these streams were forced to continue their downward cutting. Gradually, they wore new paths through the hard igneous rocks beneath. Dozens of these narrow, steep-walled pathways through granite and rhyolite have been preserved today as scenic **shut-ins**.

Because the calcium carbonate of dolomite and limestone readily dissolves in water, the bulk of the rock removed from the Ozarks during the Tertiary was carried off in solution. No mud, no sand, and no gravel were to be seen in surface run-off. However, the chert nodules and stringers imbedded in Paleozoic carbonate rocks are composed of silica and do not dissolve easily. Their fragmented remains had been left behind on the surface after each erosional phase, after each period of uplift for hundreds of millions of years. Mississippian rocks left chunks of chert behind on the Ozark surface; Pennsylvanian rocks left chert behind; so did Cambrian rocks. By the Cretaceous, the entire Ozark surface must have been strewn with an unbelievably thick layer of weathered chert debris.

When the coastal Ozark surface uplifted in the Tertiary, erosion started producing new hills in the level surface as soon as streams began down-cutting. Surface chert began to move wherever a slope developed. On ridges, gravity was foiled. Here the bulk of the chert remains, just as it has for over a hundred million years. On hillsides, however, the hard rocks began to creep slowly downward until they reached streamside. Picked up by floods, ground smooth, then tossed into piles, the chert formed sand and gravel bars. While 19th and 20th century erosion has supplemented the supply enormously, the process really began 25 million years ago when the Ozarks once again became hills.

Dozens of narrow, steep-walled pathways through granite and rhyolite have been preserved as scenic shut-ins including this one on Wallen Creek in Washington County.

Jon Hawker

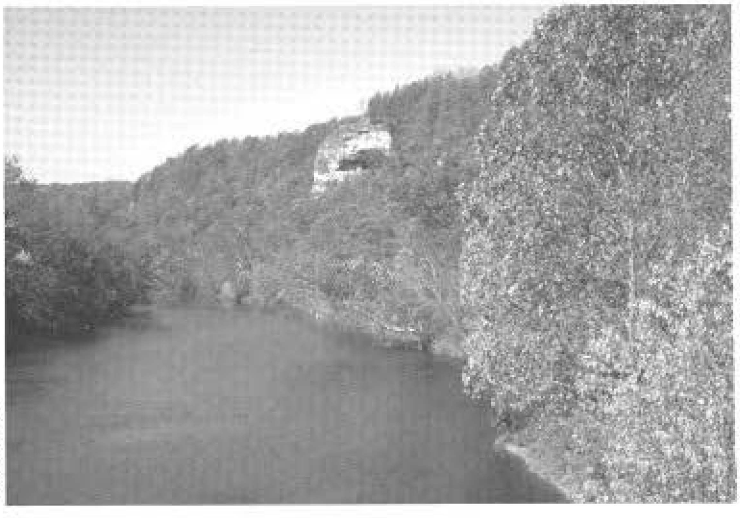
Jon Hawker

Picked up by floods, ground smooth, then tossed into piles, the chert formed sand and gravel bars.

As they wore their way into the rock layers, Ozark rivers also opened many once-hidden cave systems in the dolomites and drained some of their associated sinkholes. Many dry caves and cavities, once filled with groundwater trickling down from crocodile-infested swamps, now hang stranded high on riverside bluffs. Hundreds of feet above the stream that exposed them, it is difficult for a floater passing by to imagine the means of their creation. Some of these old caves are now slowly filling with beautiful formations as groundwater continues to trickle downward, delivering a minute load of dissolved calcium carbonate. The caves are extremely old; their intricate formations are much younger. Today, caverns are still growing in bedrock layers below stream level. These will remain filled with water, providing mineral-charged spring- and well-water, until they too are exposed by down-cutting.

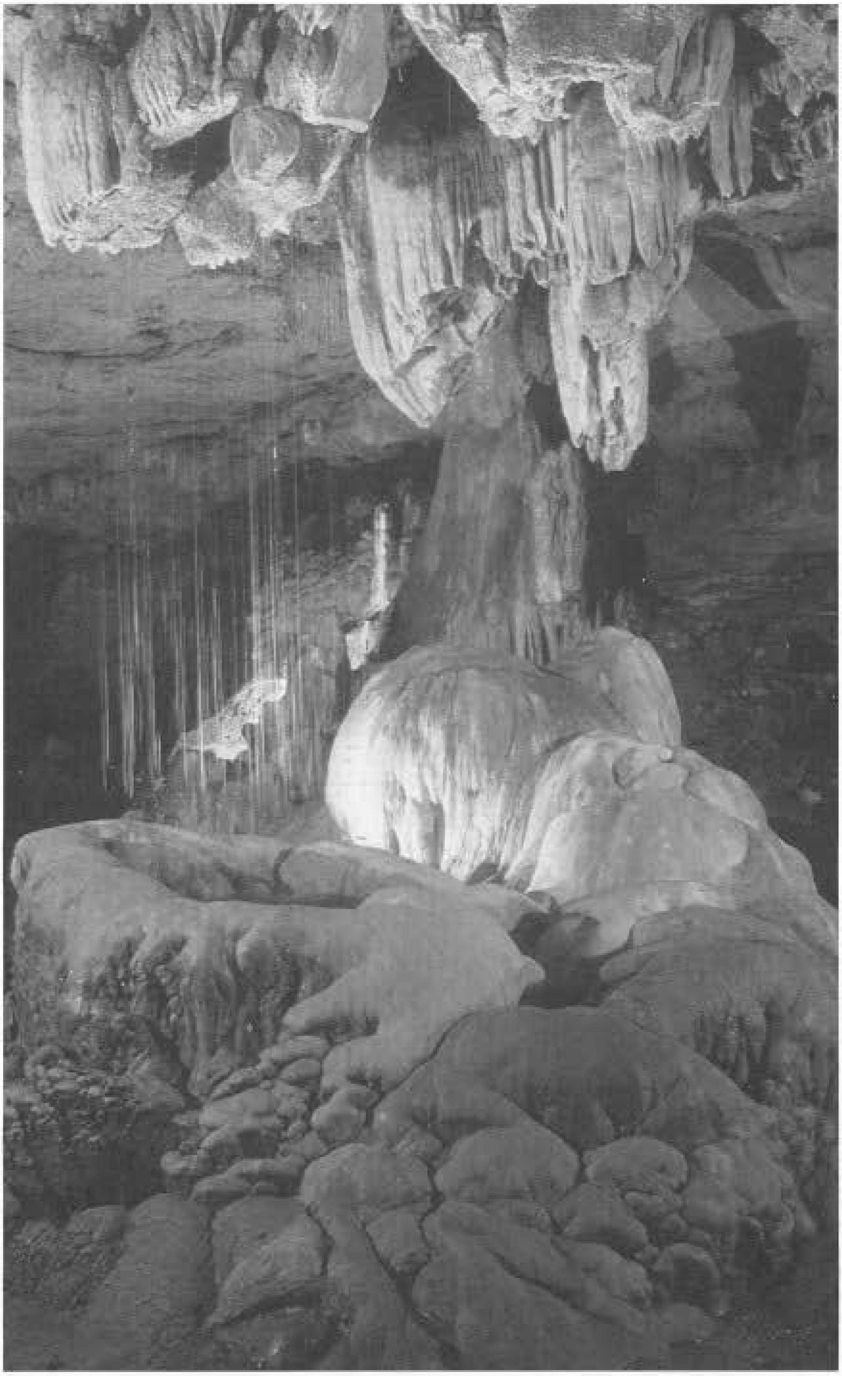
With the exception of some of the granitic knobs and deep valleys in the St. Francois Mountains, all other hills and valleys of the Ozarks, indeed all gravel bars, carbonate rock bluffs, glades, caverns, and flowing springs were created during the intense period of erosion that accompanied this third major period of uplift in the Tertiary. We may speak of the "Ozark Mountains" or the "Ozark Hills," but truthfully the Ozarks are valleys, and not really hills or mountains. The Ozark region was a flat Cretaceous coastal plain until cut by Tertiary erosion. We owe most of our Ozark scenery to this uplift and the valley-cutting that followed.

Many dry caves and cavities now hang stranded high on riverside bluffs like Buzzard Cave on the Big Piney River in Texas County.



Jim Vandike

Apart from the scenic aspects, the complex drainage pattern and rugged topography that resulted from this last uplift and erosional cycle in the Ozarks has had great biological significance. On the surface, it provided modern plants and animals with a greater number of living sites than would have been available in less dissected terrain. The next time you float an Ozark stream, try to determine the direction of flow. You'll notice the only direction you can actually rely on is downstream, whichever direction that is. Because they are deep within entrenched meanders, Ozark streams have cut channels that, at any particular point, may head north, south, east or west. As a result, their valley walls can face in any direction; they can also assume any degree of slope, from horizontal to overhanging.

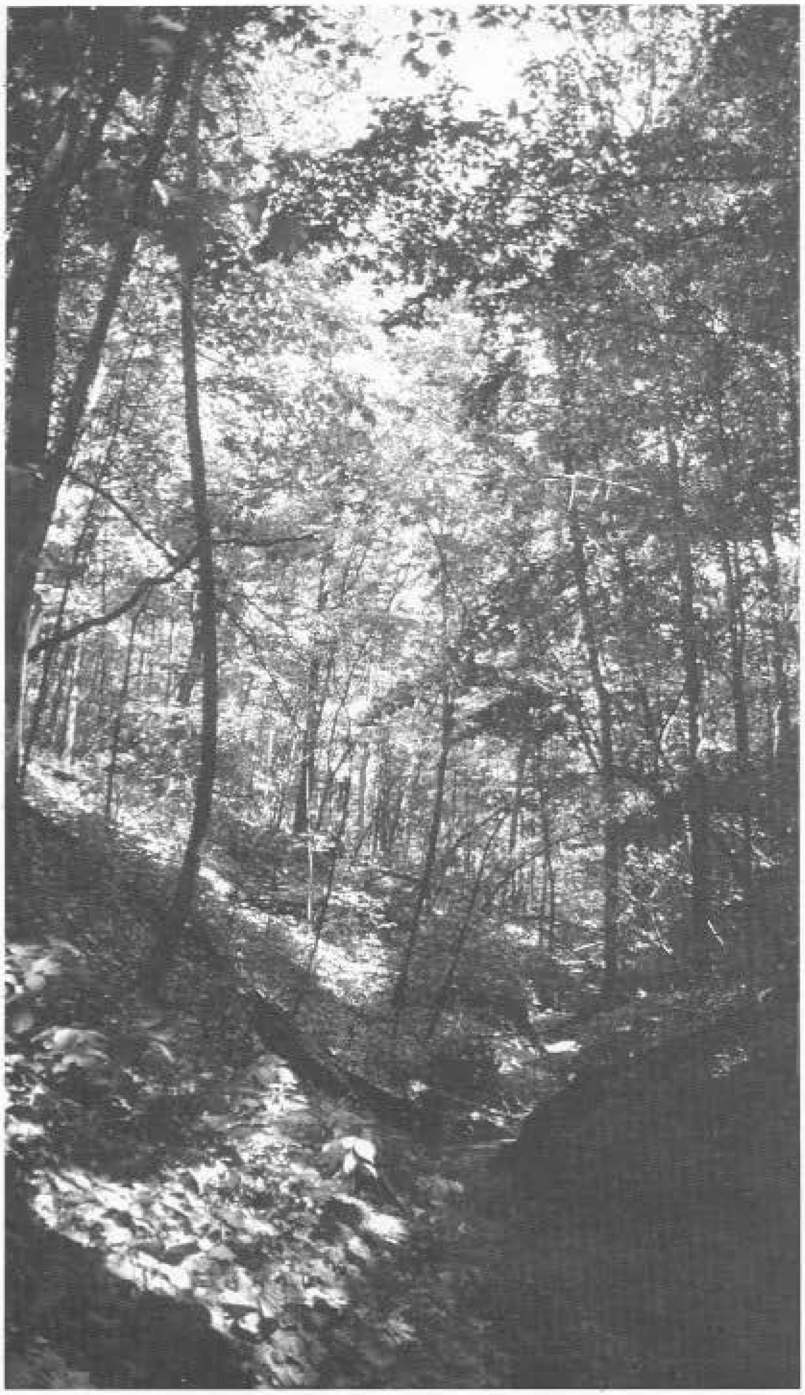

Jim Vandike

Ozark Caverns in Lake of the Ozarks State Park is one example of how old caves are now slowly filling with beautiful formations as groundwater continues to trickle downward, delivering a minute load of dissolved calcium carbonate.

Naturally, these various slopes are not uniformly exposed to sun, rain, and wind. Steep south slopes, for instance, receive the full impact of the summer sun and prevailing southwest wind. Thus exposed, leaf litter quickly dries and is carried away, leaving little organic matter to enrich soil, absorb water, or shield against erosion. Devoid of an insulating blanket of humus, the minute quantities of soil that remain are baked and become totally desiccated after a few hot summer afternoons. The exposures that are most severe - the Ozarks' desert-like glades - will seldom even support trees. Only plants that are tolerant of high temperatures and rapid evaporation rates can survive on these slopes.

In contrast, protected north-facing hillsides, inherently moist to begin with, tend to accumulate deep layers of leaf litter. This helps maintain even higher moisture levels and more moderate temperatures. In addition, the soil is continually fortified by the release of enriching nutrients from decomposed organic debris. The tall, lanky trees of a north slope stand in stark contrast to the squat dwarfs of the south side. Each different combination of degree and direction of slope produces its own exposure, that is, its own set of conditions of exposure to the elements, in which some species will prosper, while others will fail.

As the Tertiary erosion of the Ozarks cut valleys and created this array of climatic exposures, it also exposed a broad sampling of the many diverse rock types that had formed over the eons. A great variety of sedimentary and igneous rock exposures now lies at the surface, all subject to the processes of soil formation.



Jon Hawker

The contrast of intense sun and deep shade on opposing north-facing and south-facing hillsides can create strong differences in vegetation.

When rocks break down, the minerals they contain are released into the soil and become available for plant consumption. As any gardener knows, each kind of plant is more or less selective in its demands for essential minerals, just as dogs, cats, and humans each have somewhat different nutritional demands. The diverse nature of Missouri soils, resulting partially from the diverse nature of her rocks, provides for many of these different and often narrow plant preferences. As a result, extraordinary numbers of wildflowers, shrubs, and trees are able to find just the right blend of acidity, texture, and minerals necessary for their optimum growth and reproduction.

When all of the soil types that can result from different geological exposures are combined with the many differing degrees of climatic exposure available on twisted Ozark ridges, a staggering number of combinations of living conditions is produced. Each combination of conditions will eventually come to support its own special congregation of plant species. The plants, in turn, will provide food for certain types of animals and they, in due course, will feed others. As a result, whenever one particular set of environmental conditions is encountered, there is usually a matching group of plants and animals. These matched groups of plants and animals living together under a particular set of environmental conditions are called **natural communities**. As a result of Tertiary erosion, the Missouri Ozarks are populated by a tremendous variety of natural plant and animal communities. Some are unique to the Ozarks even today.

As the Tertiary uplift raised the Ozarks, the steepening gradients of Ozark streams drained the late Cretaceous and early Tertiary riverside swamps and marshes directly, while the water of most sinkholes flowed out through now-opened cave systems. Some that did not drain remain populated by the ancient mix of swamp plants. The conversion of sluggish Ozark coastal bayous to tumbling mountain streams made life difficult for the easy-going southern animal life, hardships soon to be compounded by the cooling of the glacial epoch. Swamp stragglers in the Ozarks were forced to withdraw first to the embayment region, then deeper into the southern tier of states as the rising shoreline pushed back the Gulf of Mexico. These southern species were immediately replaced by species that migrated into the Ozarks up waterways flowing down the western and northern flanks of the uplands.

A number of these western invaders were able to adapt to the rapidly changing conditions in the Ozarks and moved deep into the highland area. As they adapted and became more specialized to upland conditions, some also became trapped as the uplift progressed. The instrument that would eventually isolate some of these fish and amphibians as Ozark endemics was continued downstream erosion by their very own river systems.

As these rivers entered the lowlands, they slowed, warmed, and picked up lower levels of dissolved oxygen. As a result, downstream sections of Ozark rivers became barriers. The newly-evolved Ozark species that had developed a taste for more pristine water were now effectively prevented from leaving the uplands. And that's how you keep 'em down on the farm in an Ozark stream. Among the animal species that may have become confined to the Ozarks during this period were ancestral forms of the ringed and grotto salamander, the cavefish, the duskystripe, bleeding, and wedgespot shiners, the Arkansas saddled and yoke darters, and a wide variety of invertebrates now restricted to springs and caves. Plants that moved into Ozark springwaters or became isolated in deep ravines also began developing into new, distinct species at this time.

The Tertiary uplift and erosion of the Cretaceous Ozark coastal plain was instrumental in producing the modern Ozark landscape. Erosion created deep valleys with a great variety of slopes and exposures on which plants and animals could live, including bluffs and glades. The process opened cave systems, drained some sinkholes and isolated others, while converting sluggish, low-gradient streams to swift, floatable rivers. The uplift trapped many species and produced our Ozark endemics.

Tiny, blind cavefish have adapted to life in total darkness, living only in Ozark springs and caves. The specimen pictured here is about 2 inches long.

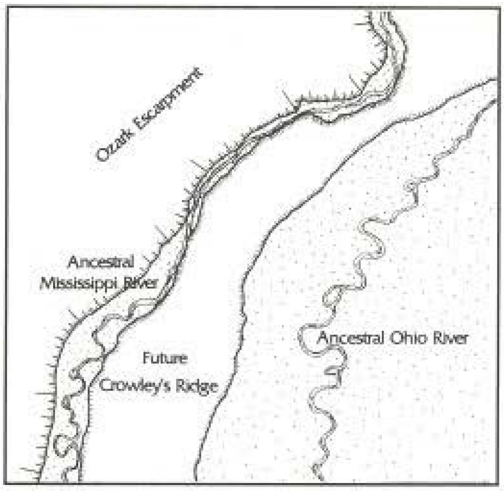
Dave Hoffman

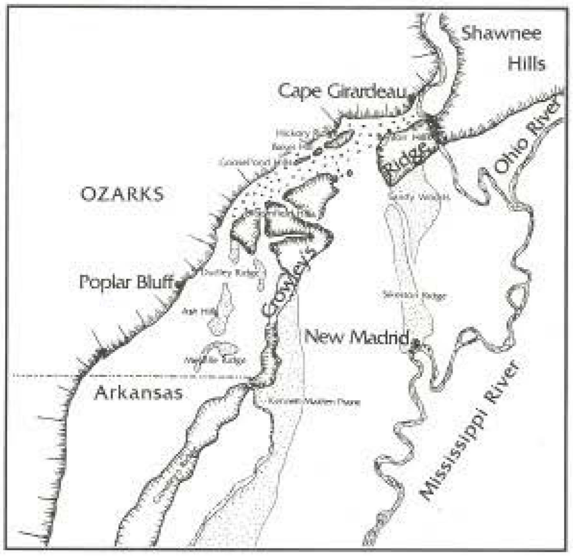
The Tertiary And The Bootheel

At the same time that the modern face of the Ozarks was being sculpted by Tertiary streams, a similar erosional process was beginning in the Mississippi Embayment. Although they had flowed gently at first, the combined erosive action of the ancient flatland rivers - including the small ancestral Mississippi and large Ohio - was increased as the Ozark uplift progressed in the late Tertiary. By then, additional Tertiary sediments, washed from the rising uplands, had completely buried the older Cretaceous muds and sands. Because the uplift also increased the height of the embayment relative to the ocean, seawaters fled the land for the very last time. Erosion of the exposed Tertiary and Cretaceous sediments could now commence.

At this time, the ancestral Ohio traced a path roughly comparable to the present course of the Mississippi, along the east side of the embayment. The Father of Waters, a mere child at the time, independently hauled its load of sediment via a parallel route, 40 or 50 miles to the west. Like an upland river, the old Mississippi also cut an entrenched path through the soft Cretaceous and Tertiary sediments down into the older and more resistant Paleozoic rocks beneath, a path that ultimately created Crowley's Ridge, the only high ground left in the Missouri Bootheel.

From where it entered the embayment region, near present-day Cape Girardeau, the shallow channel of the ancient Mississippi took it southwest along the base of the Ozark uplift. From there, it veered southward along portions of the present courses of the St. Francis and Black rivers in Missouri, then followed the routes of the Cache and L'Anguille rivers in Arkansas. Most of this route roughly parallels its present course. If the Ohio and Mississippi ever joined during this period, it would likely have been someplace in southern Arkansas, perhaps to the south and east of Little Rock. From opposite sides of the embayment, the two rivers, and dozens of others between the Ozarks and the Gulf, spent the next 10 million years hauling off sediments deposited during the Cretaceous and early Tertiary. Their


Ozark Escarpment
Ancestral Mississippi River
Future Crowley's Ridge
Ancestral Ohio River


Shawnee Hills
Cape Girardeau
OZARKS
Ridge
Ohio River
Poplar Bluff
Crowley's
New Madrid
Arkansas
Mississippi River

erosive efforts would not peak until the great Ice Ages commenced, only 2 to 3 million years ago. While most of the Ozarks were pretty much whipped into modern shape during the Tertiary, it was this next stage in earth history that would put the final touches on the Bootheel.

The Tertiary Uplift began the process of drainage and erosion that, in the Pleistocene, would produce the modern Bootheel landscape, and established the original paths of the Big Rivers to the Gulf of Mexico.

The Missouri Bootheel with its significant present-day landforms outlined (left). (Right:)A hypothetical reconstruction of how the same region might have appeared at the beginning of the Tertiary uplift. Indicated elevation differences would have been very slight.

The Tertiary And The Plains

The great sprawling grassland biome of North America could not have developed until fairly late in the Tertiary, because its rise depended on two separate and seemingly unrelated events. The first condition was the evolution and rise of the grasses. According to the Tertiary fossil record, tropical and subtropical forests extended as far west and north as the Yellowstone region of Wyoming. Even that far north, a recognizably southern temperate forest consisted of magnolia, sweet gum, and tuliptree. A distinctly Central American flora of figs, laurel, and custard apple spread up the Pacific Coast at least as far as west-central Oregon. Most of Colorado supported a similar broad-leaved forest of mountain mahogany, elm, hackberry, shadbush, tree-of-heaven, and golden rain tree; thus, by the Oligocene, some 25 million years ago, most of North America was covered by one huge broad-leaved evergreen and deciduous forest, called the **Arcto-Tertiary Forest.** But grasses and grasslands, as they are known today, did not yet exist.

While the system awaited the rise of grasses, the second condition necessary for grassland development was met with the development of substantial areas of suitably dry climates. A vast and wide-ranging episode of uplift and vulcanism began in the late Tertiary, probably associated with the dragging and colliding movements of the rapidly drifting crustal plates. This episode of continental movement - the last to alter the climate of North America in a major way - pushed up an unprecedented number of mountain ranges on nearly every continent on the globe. Trying to flow over these new ranges, maritime air masses rose thousands of feet, cooled, and dropped their moisture on the slopes. The loss of moisture caused the climates of continental interiors to shift from moist, even wet, to dry. In North America, the change was brought about by the rise of the great western mountain chains: the Sierras, Cascades, and Rockies.

These colossal masses of rock intercepted moist air masses originating in the Pacific, wrenched the water from the rising, cooling air on their western slopes, then sent the dehydrated wind on into the central forests. Robbed of their rain, the moisture-demanding forests in the interior died out. In the meantime, the continent continued its northward drift to its present position, further stressing the subtropical and southern trees with a cooling climate. In short order, the rich Arcto-Tertiary Forest vanished and was replaced by a rapidly diversifying community of plants adapted to dry conditions. The most important among these were the grasses.

The early evolution of the grass family is shrouded in mystery. The soft-stemmed and soft-leaved group has left few fossils from which it might be possible to draw a clear picture of the when or where of its beginnings. These grasses arose in response to dry habitats, and dry habitats are not very good at preserving plant remains. Some grass-like pollen grains have been discovered in Cretaceous deposits, and a few grass-like seeds have been found in 30 million-year-old Oligocene deposits, but abundant material does not appear until late in the Miocene and early Pliocene. The best evidence for the widespread establishment of grass as a dominant type of vegetation comes from indirect sources.

Because grasses are wind-pollinated, the fossil record has not permitted investigators to follow their rise by tracing the corresponding evolution of their pollinators, as has occasionally been possible with fossil beetles, bees, and butterflies. However, all of today's grasslands offer an immeasurable supply of nutrients and energy, and support huge numbers of animals. It is likely that the earliest

Jon Hawker

Today's grasslands offer an immeasurable supply of nutrients and energy.

grasslands would have offered similarly rich sources of food. New grasslands were undoubtedly exploited by herbivores as soon as they became available. In fact, by examining the teeth of fossil herbivores, it has been possible to trace the course of grass-eating mammals and other animals, groups that could have evolved only as grasslands became available.

During the late Miocene, a rapid diversification of animals with high-crowned, grass-chewing teeth becomes obvious in the fossil record. The more primitive herbivorous mammals of the early Tertiary forest mashed soft foliage with low-crowned, relatively weak teeth. The advent of harsh grasses, heavily impregnated with tough, indigestible fibers and crystals of glass-hard silica, offered these mush-mouths a particularly challenging source of nutrition. For early Tertiary mammals, living on grasses would have been roughly comparable to subsisting on a diet of scouring pads.

About 25 million years ago, primitive horses, camels, rhinoceroses, pronghorns, and other mammals in North America began to develop teeth that continued to grow even as they wore down. The development of grazers and grasslands seems to have accompanied the shift from warm, moist forest, to drier, more temperate conditions in the central region of North America that was rapidly becoming the Great Plains. With the onset of world-wide mountain-building in the Tertiary, grasses were able to radiate and spread across millions of square miles of drying terrain. As a result, a completely new set of lifestyles became available in the grasslands of each continent.

These new roles were quickly exploited by any species capable of rapid evolutionary change. In North America, the horse, camel, rhinoceros, peccary, and pronghorn families, many of which were originally composed of browsing forest animals, developed the grazing habits and lifestyles that were suited to open terrain. Most of the strict forest browsers among them would later become extinct. The new hoofed grazers joined many other trial grassland species, including rabbits, burrowing beavers, ground squirrels, and many other rodents.

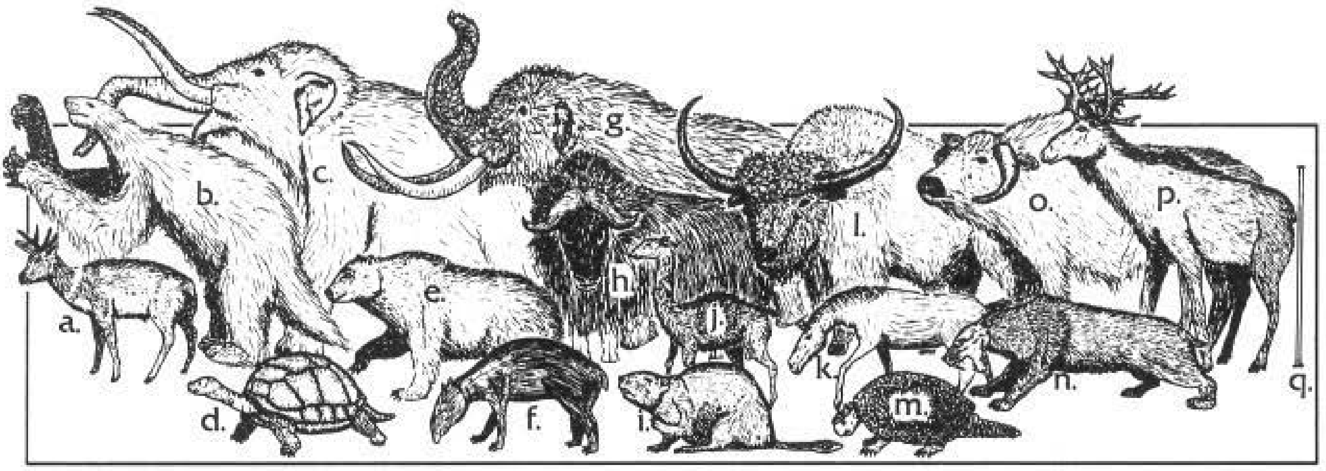
A wide range of hyena and dog-like predators developed to take advantage of the expanded offering of herbivore prey. Similar groups of animals have dominated the plains of North America and other continents ever since.

In South America, an array of marsupial predators, similar to the dogs and cats of today, arose as predators of the new grazing mammals. Herbivores, omnivores, and minor carnivores, such as giant ground sloths, glyptodonts, armadillos, anteaters, rodents, and large flightless birds, soon roamed the spreading pampas. These animals, strange as they are to us, shared the southern grasslands with even stranger groups of mammals, all of which have since passed into extinction.

Roughly comparable in design and habits to the familiar hoofed animals of North America, like bison and pronghorn, these unique South American hoofed grazers have been assigned to orders with names like Pyrotheria, Condylarthra, Xenungulata, Astrapotheria, and Litopterna. All these unusual pilot projects in mammalian evolution, although successful for millions of years in the isolation of South America while it drifted by itself, exist today only as fossils. They were all eventually replaced by North American and Eurasian grazers, like camels, that wandered south across the Middle American land bridge late in the Tertiary.

In Eurasia, a third entirely different group of mammals responded with equally phenomenal diversification, leading to the development of cattle, buffaloes, antelopes, gazelles, giraffes, goats, and sheep. From their homes on the rapidly developing steppes of central Asia, these bovines spread into Africa, where they quickly gained control. Today, their descendants still dominate the vast grasslands and savannas of the veld. In the long-isolated continent of Australia, a fourth group of grazers, the kangaroos and kangaroo-like marsupials, evolved to fill the grassland niches of the drying Outback.

While our forests have been around, largely unchanged, for over a hundred million years, the great grassland biomes of the world, including the North American prairie, probably extend back in time only as far as the late Oligocene or Miocene, roughly 20 to 25 million years. It is unlikely that grassland entered Missouri until some time after its origination. The dry plains only spread eastward in response to the rise of the mountains. Since this process required millions of years, the forests of western Missouri likely held their own for a corresponding period; nevertheless, rhinos, zebras, pronghorns, and camels roamed the prairies of Kansas at least seven million years ago.



A parade of Pleistocene megafauna compare their relative sizes to a 6-foot measure(q). They include (d) a giant tortoise, (f) a tapir, (i) a giant beaver and a (m) glyptodont; (a) a pronghorn ancestor, (e) a short-faced bear, (h) a musk ox, (j) a llama-like camel relative, (k) an early horse, and (n) a saber-toothed cat; (b) Jefferson's ground sloth, (c) a mastodon, (g) a mammoth, (l) a giant bison, (o) an early cow relative and (p) a moose-elk. These were not necessarily all living at the same time nor in the same place.

Massive Tertiary mountain-building events around the world dried the climates of continental interiors, leading to the development of grassland biomes - pampas, steppe, veld, Outback, and North American prairie. This chain of events was accompanied by a radiation of grass-eating mammals and other grass-dependent animals.

During the **Pliocene Epoch**, at the close of the Tertiary Period, many groups of mammals had evolved that would be easily recognizable today. By six million years ago, when the Isthmus of Panama was just forming, some of these would pass south into South America. Others would come north. More important to the mixing of the world's species, Siberia and Alaska had been drifting together and splitting apart off and on for millions of years. Despite the rifting of Laurasia and the development of the Atlantic, Eurasia and North America had remained in nearly constant contact throughout the Tertiary along their Pacific boundaries. This allowed an ongoing reshuffling of floras and faunas between the old Laurasian partners.

In the Pliocene virtually all plant families had evolved modern-looking species. Forest and field might actually have seemed like home at first glance. The animals might have given us a clue that things were not as they seemed. Ancestral horses grazed the drier uplands of North America, including Missouri, and mingled with primitive browsing deer and camels, which resembled the llamas and guanacos of modern South American grasslands and mountains. More easily recognizable shrews, gophers, squirrels, rabbits, and mice burrowed or crept at ground level. Missouri rivers still supported several species of gar, bowfin, paddlefish, and sturgeon, but now all kinds of modern bony fish - herring, catfish, and perch, as well as sticklebacks and minnows - filled the watery world.

However, a large number of strange-looking mammals occupied the Missouri environment, along with all sorts of reptiles, amphibians, and birds, also now extinct. These would certainly have proven that we were not at home. Shovel-jawed mastodons gulped huge mouthsful of vegetation from shallow marshes along rivers. The giant sloths, whose weight would have smashed ordinary trees flat, fed from the ground and yanked branches within reach with enormous claws. These grazers and browsers were stalked by saber-toothed cats and large predecessors of modern canines called dire wolves. In short, the mammals had reached the peak of their diversity and all habitats were occupied by a wealth of species that are now extinct.

In some ways, the animal life of the late Pliocene was far different than today and would have provided surprises at every turn; but, because most of the plants and many of the animals have recognizable ancestors today, it was a world to which one would not have had great difficulty adapting.

During the latter part of the Pliocene, one of the most useful of the Bootheel sediments was deposited at the very top of the Tertiary sediments. Dubbed the **Lafayette Formation**, these brilliantly colored sands and gravels consist of water-worn and highly polished bits of ordinary brown chert typical of the Ozarks, plus shiny gems of black chert, white quartz, and purplish or pinkish quartzite, as well as rounded chunks of ordinary dolomite and limestone, all loosely cemented together with a multi-colored sandy clay.

The ancient streambeds that laid these colorful sands and gravels partially sorted the grains by size and deposited them in irregular and indistinct layers of varying thickness. In places, the Lafayette sands and gravels were piled to depths of 60 feet or more. Scooped and scraped from pits all along Crowley's Ridge for use in concrete and paving, the sands and gravels capping the hilltops are one of the most distinctive and economically important features of the area. Their formation remains something of a mystery. Were they the last of the Tertiary erosional features, or the first of the glacial features to come? No one knows.

The great Tertiary Age of Mammals came to a close when the Pliocene Epoch ended. It is impossible to assign an exact point in time when the Pliocene Epoch became the **Pleistocene Epoch**, the time of the glaciers, but the coming of these massive ice sheets began a period of decline for the warm-blooded rulers of the Tertiary. From north to south, the ice also put the finishing touches on the Missouri landscape. The heavy hand of glacial ice would be applied most directly on northern Missouri, but its indirect effects would be felt far beyond the edge of the grinding sheets.

The heavy hand of glacial ice would be applied most directly on northern Missouri.

The Tertiary Period was a time of major world-wide upheaval that led to the formation of the grassland biome and the rise of mammals and birds. This and the Ozark uplift that occurred during the last 30 million years of the Tertiary Period were of the utmost importance to Missouri biology.

The Pleistocene- Missouri Geology: Last Scene, Last Act

The great continental glaciations of the Pleistocene Epoch - the **Ice Age** - were of immeasurable importance in altering the landscape and species composition of the earth. Biologically, the comings and goings of the ice reinforced the fundamental similarities between North America and Eurasia originally established by continental drift, and moved major biomes from north to south, and back again, mixing species with abandon. The ice flattened much of the land, created new soil, and altered landscapes hundreds of miles from its actual contact.

The four continental glaciations usually referred to as the "Ice Age" are lumped by scientists into a single geological period that spans most of the last two or three million years, the **Pleistocene Epoch**. The term "Pleistocene" is derived from two Greek words meaning "most new." Aptly named, the Pleistocene is not only the "most new" global geological event, its ice sheets also created the "most new" Missouri landscapes as well. While the Pleistocene glaciations represent our familiar "ice ages," they are not the only continent-wide ice sheets to have formed on the earth.

Periods of continental glaciation have occurred in various places on the earth throughout geological time. A billion years ago, during the Precambrian, great masses of ice formed in North America on at least two occasions, and others developed at least once during that era on each of the other continents. In the Paleozoic, during the Ordovician and Pennsylvanian Periods, while much of Missouri was covered by steamy tropical seas crawling with trilobites, crinoids, and brachiopods, two other sets of glaciers crept over the southern part of the ancient Pangaean supercontinent.

There have undoubtedly been many natural forces at work to produce such widely spaced climatic events; however, the regularity of ice advances in the Pleistocene of North America suggests that their cause results from some understandable and predictable phenomenon. When the probable causative agents are examined closely, however, it soon becomes apparent that a single factor will not explain the orderly advance and retreat of continental ice sheets. Several concurrent mechanisms must occur simultaneously to produce an ice age. Geophysicists tell us that a certain coincidence of the earth's irregular elliptical shape, the angle of its axis, and the wobbling that occurs as it spins on its axis are all necessary for the creation of suitable climatic conditions. These three mechanisms coincide at times to alter the surface area of the earth relative to the sun's rays. In turn, the change in surface area affects the amount of solar heat absorbed or reflected from the earth's extreme northern and southern latitudes.

Taken together, these perfectly normal irregularities of the earth's shape and spin are sufficient to account for the cycles of climatic change that alternately cool and warm the planet roughly every 40,000 years. Whenever the planet has been in a position to absorb greater amounts of solar energy, a warming trend has followed. When the earth's reflectivity has increased, global cooling soon began. By themselves, however, even these periodic cold spells did not always create massive glaciers.

The positions of the continents are also fundamental to the formation of major ice caps. To grow, an ice cap needs a firm foundation. As the continental masses drift about, they not only approach Arctic or Antarctic regions on occasion, placing them in a position to adopt a growing glacier, they also increase the likelihood of ice formation by interfering with the normal circulation of ocean currents. Such currents are crucial to the climates of nearly every geographic region of the world.

If warm currents are blocked and cold currents are redirected, a significant lowering of the mean annual average temperature of a continent can result. Once a cold spell has begun due to a regular shift in the earth's position relative to the sun, the additional cooling that results from altered ocean currents can blossom into a major glacial period.

To develop, an ice age does not really need horribly cold, Arctic-style winters, though such conditions would certainly speed things up considerably. Obviously, there are many places, like Buffalo, New York, where the winters are bitterly cold every year and dreadful amounts of snow threaten to smother the residents. However, as long as the snow melts completely each summer, no glacier will ever form. Conversely, on the North Slope of Alaska, it is certainly cold enough to produce glaciers, but limited amounts of precipitation prevent significant ice formation.

What a glacial period really needs is a supply of moisture adequate to produce large quantities of snow, coupled with a few thousand summers too cool to prevent the complete thaw of snow from the previous winter. Only under such conditions will the deposition of large amounts of new snow each winter eventually produce a glacier.

Whenever a blanket of snow is exposed to air that is near the freezing point, it quickly looses its light, fluffy texture. Like the loose cubes in an ice maker, the flakes refreeze into rounded granules of ice. Each ice granule enlarges slightly as it latches on to water seeping down from melting layers at the surface. In addition, adjacent granules begin to fuse with each other as their ice melts and refreezes in response to the pressure at their mutual points of contact. Large granules grow quickly at the expense of their smaller neighbors. After several weeks or months, a mass of pebbly ice crystals is produced. This process of snow accumulation and conversion to ice is called **nivation** and its various stages can be observed in any mountainous place in the world where alpine glaciers still grow.

Over the years, as the inches of snow become feet and the feet become yards, the granules at the bottom, now called **firn** (from the German, "of last year"), become compressed and soon coalesce into a solid mass. When the snow has built to a minimum depth of about 100 feet, the rounded granules of firn fuse into solid ice. Their pebbly texture disappears as the immense weight of the growing pile squeezes the air from between individual crystals, like the inconsiderate conversion of a snowball to an iceball by continued packing and squeezing.

With increasing depth, the enormous pressure produced by hundreds of feet of snow and firn begin to extrude the massive ice at the bottom as if it were a thick fluid, like molasses. The entire circumference of the developing ice cap creeps outward as its central mass continues to grow. The ice need not even form in an elevated position to flow. On level terrain its own central weight can provide pressure that is far greater than the force of gravity at its periphery. While a glacier prefers to move down hill, it can also move across flat ground, and can actually climb up hills and over ridges if it acquires a large enough mass.

The glacial sheet, like a gel, is forced by its own immense weight into cavities and hollows. Scraping and gouging everything in its path, the glacier moves away from the center of snow accumulation and ice formation. Jammed against the surface, the bottommost ice melts under the enormous pressure, lubricating the surface and allowing the

Jon Hawker

Glacial ice can carry material of all sizes, even boulders larger than a house.

glacier to glide. This water also seeps into tiny cracks and crevices, then refreezes and expands, fracturing the underlying surface. Bits and pieces of rock, sticks, logs, particles of soil, and the odd caveman are surrounded by the enveloping ice, then frozen into the matrix.

Dust, spores, pollen, smoke, leaves, and insects, fallen with the snow or blown onto the surface later, become buried and encapsulated in the developing ice, producing dark bands and lines similar to the growth rings of a tree trunk. Whether picked up from below or captured from above, all manner of debris is carried along with the ice. Unlike a stream, glacial ice can carry material of all sizes, even boulders larger than a house. As it moves, the ice shears, deforms, melts, and refreezes, mixing and obliterating the horizontal strata that initially marked each year's accumulation of snow.

As the glacier expands, its ability to scrape and transport increases dramatically. Once the ice cap is fully formed, it has the capacity to carry off whole hills and level entire mountains. Contrary to what might be imagined, an ice sheet does not ordinarily push these enormous loads of rock and soil, called till or glacial drift, in front of it like a giant bulldozer. Most of the material is collected from beneath, particle by particle, and piece by piece, as it is broken free and lifted up into the ice over a period of many centuries.

The surface of the bedrock is leveled only a fraction of an inch at a time. In stages that are barely perceptible, prominent topographic features are ground down and disappear. In some cases, a glacial front that has temporarily receded may surge forward again and push over its own till, left in a heap by its earlier departure, and reform it into distinctive, crescent-shape mounds called **drumlins**. Most of the irregular piles of drift it leaves behind, called **moraines**, are never restructured in such artistic ways. Moraines the size of hills often dot landscapes where continental glaciers have crept.

The till that is picked up, like the material carried along by a stream, serves as the primary agent of abrasion in the relentless carving of the terrain. The boulders, cobbles, and gravel imbedded in the ice grind against each other, removing rough edges and rounding individual stones. As the till is dragged across the bedrock, it scours the surface and may scratch deep parallel grooves or striations, called **striae**, on its surface. The fine particles of gritty rock dust that are removed during all of this grinding, scouring, and scraping remain trapped in the ice and serve as a final polishing medium for any surface the ice contacts.

Later, this same fine grit, called **rock flour**, is responsible for the milky appearance of meltwaters escaping from the receding face of a glacier. In the end, the rock flour may be laid down as silty alluvium along riverbanks downstream, picked up by the wind, and deposited on the surrounding hillsides in thick layers of dust, called **loess**; or it may be contributed to the delta at the river's mouth.

Larger chunks of rock and gravel, carried only a short distance by the meltwater as it flows beneath the ice, may be deposited in long, sinuous bars under the ice. These low, snaking ridges of gravel and cobbles, called **eskers**, may be left behind as prominent topographic features long after the ice has gone. If there had once been eskers, drumlins, or moraines in Missouri, they have all been eroded and weathered into oblivion. Most of our tills were composed of rocks so soft that even they have been broken down to mud.

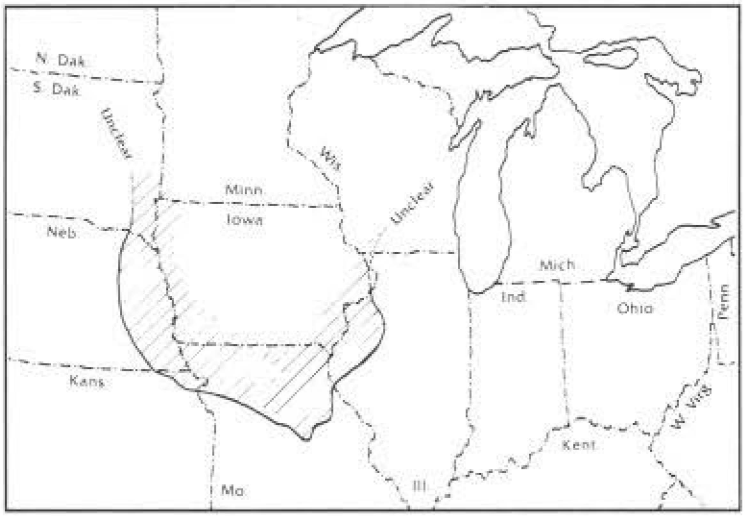
From the regions east and west of Hudson Bay where the glaciers formed and grew, the great ice sheets ground their way south toward Missouri across thousands of miles of hilly, forested terrain, removing virtually every distinguishable geographic feature present at the time. Many areas of Canada display extensive expanses of flat, barren rock, etched by the glaciers and scarcely colonized by vegetation in the thousands of years since the last ice melted. The continental glaciers carried their incredible loads of materials far to the south, depositing it in the distinctive forms of drumlins, eskers, and moraines in Minnesota, Wisconsin, northern Illinois and Indiana, and in broad, featureless till or drift plains in Iowa, Illinois, and Missouri.

The newer glacial deposits of Minnesota, Wisconsin, and Michigan, derived from the hard, resistant Precambrian rocks of the Canadian shield and abraded for only a short distance from their source, contain heavy concentrations of coarse sand, cobbles, and large boulders. These deposits resulted from the retreat of the very last ice sheets and they retain a fresh, sharp appearance, clearly attributable to glacial ice.

The tills laid down in northern Missouri, gathered mostly from the softer Pennsylvanian sandstones, limestones, and shales of Minnesota, Wisconsin, Iowa, Illinois, and northern Missouri, consist mainly of fine sand, silt, and clay. Since this drift is extremely old and highly weathered, it displays few traces of the ice that gave it birth.

With the passage of time, a variety of physical forces have completely decomposed most fragments of rock originally present in Missouri till into silt and clay. There are a few thin beds of durable chert and quartzite gravels laced through the muds of Missouri drift, but most of these gravels are of local origin and were probably polished more by pre-glacial or post-glacial stream abrasion, than by their brief transport in ice.

The extent of the Nebraskan advance as near as can be deciphered.



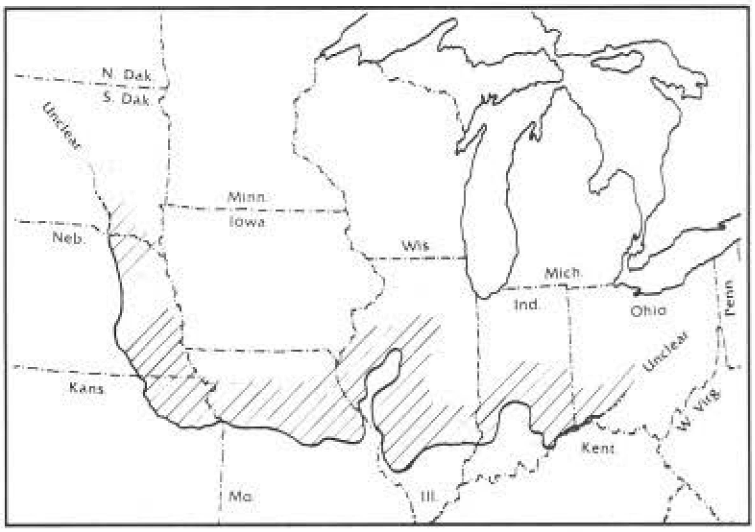
On the other hand, some of the larger and tougher rocks from sources in the northern states and Canada did make it as far as Missouri. Occasionally, glacial-polished chunks of granite and other similar igneous rocks, pink quartzite, silvery gneiss, and other metamorphic rocks - even bits of native copper and gold - are found in Missouri till. These foreign rocks and minerals are known as **glacial erratics** and they become much more common the farther north one goes.

Ice sheets, like modern glaciers, often act like gigantic amoebae. Their edges ooze outward now, draw back then, poke a finger of ice here, pull in a little there, often in seemingly random patterns. Each continental glacier did not simply come and go. From recent studies, it is now clear that there were actually eight or nine minor ice advances scattered among two dozen climatic fluctuations during the Pleistocene. Geologists in North America usually lump these many smaller advances into four major periods, each named for an area where the period's ice sheet was first studied and described.

Of these four principal ice advances, only the first two, the Nebraskan and Kansan, had significant and direct effects on the topography and soils of Missouri. The oldest, the **Nebraskan**, occurred sometime between 1.7 and two or three million years ago. This ice sheet flattened most of the original land surface of northern Missouri, filling in old valleys and riverbeds and removing the tops of hills. Deep wells drilled into the till reveal some of the region's preglacial drainage patterns and give us an idea of the rolling topographic features characteristic of the original bedrock surface.

Evidently, this first ice sheet halted along a line just to the north of the present Missouri River. For tens of thousands of years or longer, it remained nearly stationary. Evidently a balance was finally struck between the rate of ice formation at its source and the rate of melting along its leading edge. Even though its advance was halted, the glacier continued to grind away at the face of northern Missouri, very much like the treads of a bulldozer mired in mud. Ice kept pushing in from the north, even as the leading edge melted away.

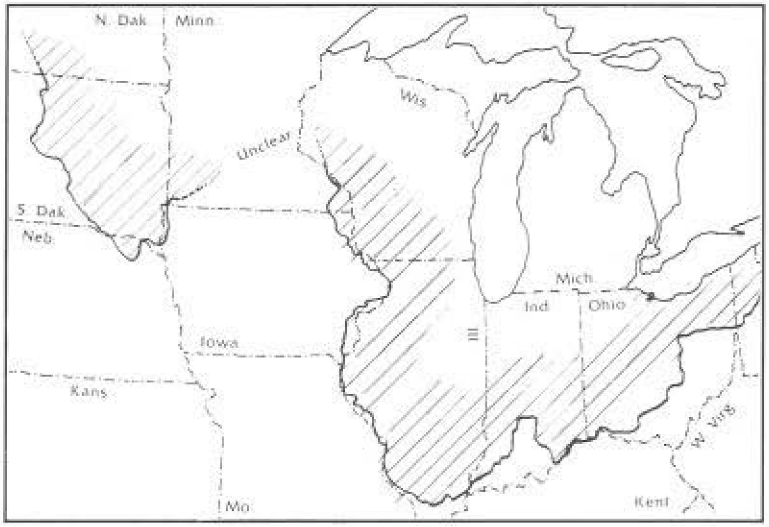
A quarter million years later, nearly all evidence of the passing Nebraskan ice was subsequently buried or scraped away by the second major advance, the **Kansan** glacier. Even had it been a more powerful and enduring ice sheet than its predecessor, the Kansan would still have had fewer topographical effects in Missouri because most of the region had already been completely flattened. However, Kansan ice did creep a bit farther south, eventually stopping just about where the Missouri River flows today. The Kansan ice thus put the finishing touches on our northern Missouri plains, removed some highland remnants of the original landscape missed by the Nebraskan sheet, and re-leveled any hills or valleys that might have begun to erode in the Nebraskan till.



The Kansan sheet pushed farther south into Missouri than any other glacier.

The third great glacial stage, the **Illinoian**, from 125,000 to 500,000 years ago, may not have entered northern Missouri at all, but did have some impact on thin strips of land bordering the Mississippi Valley. A tongue of ice extending from this sheet seems to have covered the area that is now St. Louis, for a time forcing the Mississippi River around it to the west, through Forest Park, and back along the Mill Creek Valley. Later, the river was forced farther south, then east along the present course of the River des Peres. The broad valleys of Mill Creek and the River des Peres were both cut by a big river, not by the little streams that wander through them in modern times.

A bit farther north, in St. Charles County and beyond, a similar damming event seems to have occurred. Here, a vast layer of sediment was deposited on the bottom of a glacial lake created by another



The Illinoian glacier barely touched the eastern borders of Missouri.

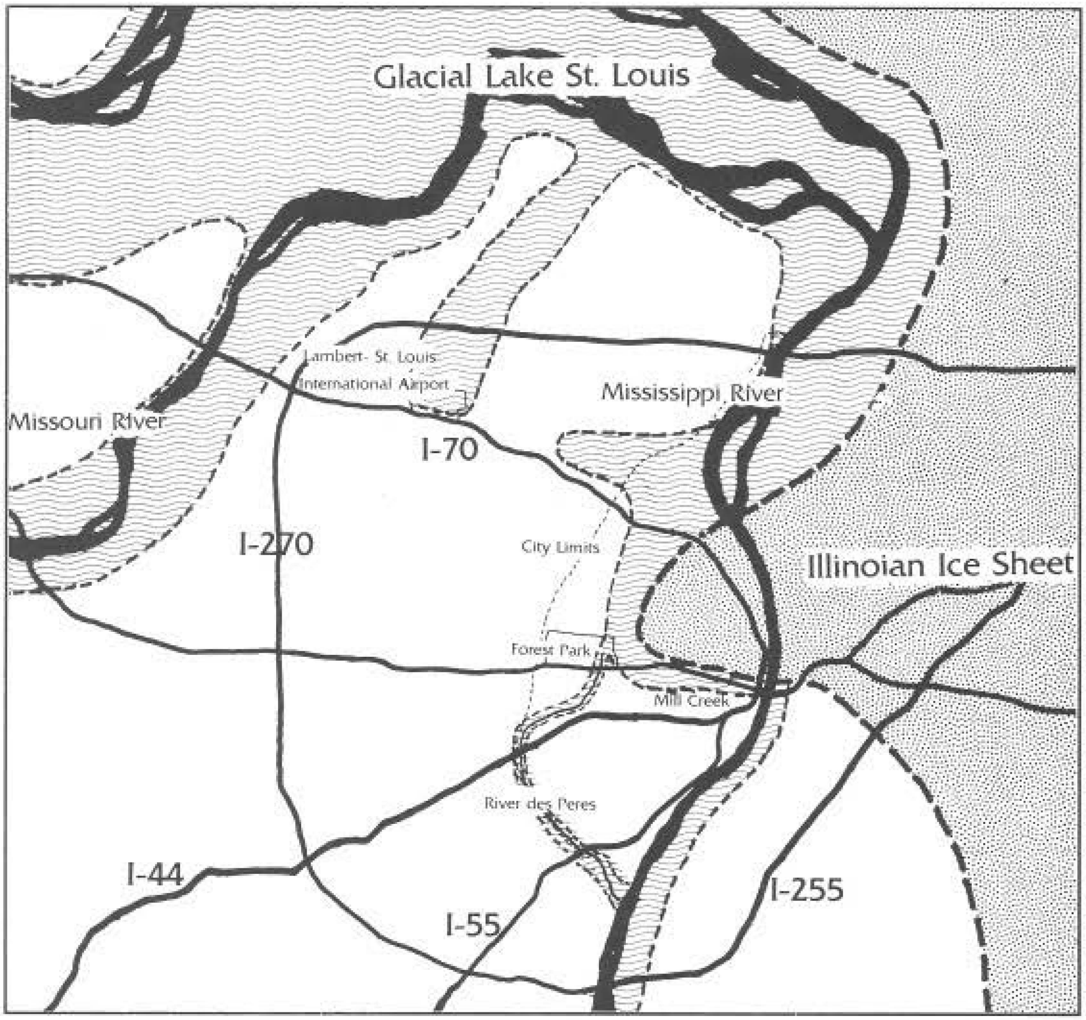
Illinoian age ice dam. This particular lake deposit is still clearly visible today as a series of high terraces along the Cuivre River and many of the small nearby streams that drain into the Mississippi. Similar "Pleistocene river terraces" are seen along other streams, but do not always indicate the former presence of a lake. Many similar terraces were created by silt deposition during the flooding cycles at the end of each ice advance and by down-cutting since.

Illinoian ice also left its signature along the extreme eastern edge of the Ozarks, south of St. Louis, although its actual presence is doubtful. While at its full extent and later, as it began to recede, the Illinoian sheet and its outwash may have once again dammed the Mississippi. The overflow carried chunks of ice, along with their trapped debris, over and beyond the bluffs, which at the time were not nearly so high. Till deposits on bluffs north of Ste. Genevieve, and erratics as far as eight miles inland, seem to point to the presence of such a glacial lake, and perhaps to the presence of the glacier itself. For a time, the Mississippi may have filled or flowed through the lowlands of the present Establishment Creek.

While evidence of its physical presence is barely discernible, the Illinoian ice nonetheless left an indelible mark all across the Missouri landscape. As the ice withdrew, it left a trail of extremely deep loess deposits on the bluffs and hillsides bordering the Big Rivers. From Nebraska to Memphis and beyond, Illinoian loess is one of the most significant features left by this glacial stage (about which there will be more later).

The last glacial stage, the Wisconsinan, did not enter Missouri at all. Formed during what may have been the coldest glacial period, the mighty Wisconsinan sheet created the modern landscape of the entire Great Lakes region. In its wake, it left the broad, flat eastern Illinois prairie, the moraines of Wisconsin, and the "land of 10,000 lakes" in Minnesota. But its ice fell far short of Missouri.

Like the Illinoian sheet, however, the Wisconsinan left huge deposits of loess, chiefly along the Big River bluffs as far south as Tennessee and Mississippi, but also in a layer of variable thickness over most of Missouri and Illinois. Blown over older soils that had either formed in the blanket of Illinoian loess, in the eroded layers of Kansan and Nebraskan till, or in the underlying Mississippian or Pennsylvanian age bedrock, the Wisconsinan loess became the parent material for many of Missouri's most valuable modern soils.



The Greater St. Louis area during the Illinoian Advance, showing the approximate position of a tongue of ice that dammed the Mississippi creating a temporary lake, and sent the river through Forest Park and south along the present course of the River des Peres.

With the exception of the two new layers of Illinoian and Wisconsinan loess and their subsequent erosion, no major topographical changes have occurred in Missouri for the last million years. At most, a minor brush with glacial ice touched some small sections of Missouri during the Illinoian advance some 350,000 to 400,000 years ago. For hundreds of thousands of years, since the demise of the Kansan Glacier, the Missouri landscape did not change much.

Once the Nebraskan and Kansan ice sheets retreated, the till they left behind began to form soil. Because soils reflect the physical conditions of their environment, as well as the material that creates them, it has been possible to draw a fairly accurate picture of the climate and topography of the region during the periods between glaciers. By studying the attributes of these old, long-buried soils, and adding the information that can be derived from fossil plant and animal material to the analysis, we can form a fairly complete picture of these ancient landscapes.

Of the four major glacial advances in North America, only the first two - the Nebraskan and Kansan - actually scoured the northern Missouri landscape; however, Illinoian and Wisconsinan loess blankets much of the state. Many of our modern agricultural soils owe their fertility to these till and loess deposits.

After An Ice Sheet Was Finished

The physical appearance of the northern Missouri surface following each of the first two ice sheets was roughly the same. During the first or Aftonian Interglacial, a period of roughly 250,000 years between the departure of the Nebraskan ice sheet and the arrival of the Kansan, northern Missouri was nearly level and, as a result, was very poorly drained. At the height of this relatively warm period, the appearance of northern Missouri was probably quite similar to the modern surface of north-central Illinois or North Dakota prior to settlement. Both were predominantly flat, marshy landscapes, sprinkled with occasional low, rounded moraines left by the recent retreat of the Wisconsinan ice sheet. Either would be a good model for understanding what must have been happening 1.5 million years ago in northern Missouri.

The receding Nebraskan ice left an area of low relief, with a very shallow, inefficient herringbone drainage pattern of sluggish, meandering streams. Most upland areas would have had high water tables, broad patches of marshy ground, seasonal ponds, and perhaps even a few lakes of considerable size. The pothole country of North Dakota presents a vivid image of how northern Missouri probably appeared. The Aftonian surface likely remained relatively flat and wet for most of its brief life. There was insufficient time between the glaciers - only a quarter of a million years - for erosion to cut a deep system of valleys capable of completely draining the Nebraskan drift. Of course, any drainage system that did develop was subsequently wiped out by this second sheet.

Initially, the surface of northern Missouri in the post-Kansan period, known as the **Yarmouth Interglacial**, would have been just as flat and poorly drained as the post-Nebraskan, perhaps even more so. In contrast, however, a million years of erosion has drained its excess moisture and carved a terrain of rolling hills and sluggish, meandering streams, the characteristic features of northern Missouri today.

The Ice And The Big Rivers

Like the bluffs of the Ozarks, the Missouri and Mississippi river bluffs were largely carved after the Tertiary uplift. Unlike the Ozark canyons, however, these Big River canyons were assisted by a huge volume of glacial meltwater. At the ends of glacial periods, as these rivers cut deeper, the growing bluffs must have provided rather unique conditions for plants and animals, just as they do today. During glacial advances, the stretches of the rivers closest to the ice sheets were flanked by tundra vegetation, lush with mosses and lichens. The drainage of cold air along the valley floor from the ice sheet to the north, coupled with the chilling effect of icy meltwater cutting through the flood plain, allowed many members of the dark boreal forest, the Canadian evergreen forest, to infiltrate far to the south, at least as far as Memphis, Tennessee. Warmer air high up on the bluffs evidently permitted many Ozark deciduous trees to survive.

The close association of the two forest types is well-documented in the fossil record. The loess along the bluffs and flood plains in St. Louis County, and in Memphis, Tennessee, among other places, have yielded well-preserved butternuts, hickory nuts, and acorns, mixed with the wood, needles, and cones of white spruce, larch, and fir. Similar treasures turn up in old backwater deposits and behind ancient beaver dams constructed on small tributaries. The combination warm-and-cool effect still exists along our bluffs. The juxtaposed climates have produced the pairing of Missouri's most "northerly" forest type, the sugar maple and basswood forests of north-facing bluffs, with typical Ozark oak and hickory higher up on ridges and beyond the crests on southern slopes.

During glacial periods, the big river flood plains must have been the worst of all possible worlds for plant and animal life. During the summer months, silt-laden meltwaters poured over the entire 4- or 5-mile valley floor, from bluff to bluff. Each winter, as melting temporarily ceased, the bottomland was converted to a barren, windswept mudflat, dried or frozen. It is unlikely that anything at all could have survived on the bare soil of the flood plain during this entire period. With its surface unprotected, the chill winter winds were able to blast the flood plain and carry off enormous quantities of silt that would become loess, the characteristic feature and chief soil-forming material on nearby bluffs and hillsides.

The Ice And The Bootheel

The first of the continental glaciations was also the beginning of the last major period of alterations leading to the present appearance and soils of the Bootheel, Missouri's Southeastern Lowlands. The preglacial rivers of the embayment region were mostly minor streams and drained much smaller watersheds than at present. In particular, the Mississippi was not nearly as large as it is today. A large percentage of the runoff from the northern parts of the continent, including the contribution made by the Missouri River and a substantial part of the Ohio, drained northward through the Great Lakes region (the lakes had not yet formed) and into Hudson Bay.

In similar fashion, one ancestral branch of the Mississippi drained directly from the Great Lakes region, while another fork curved southeastward from southern Minnesota through central Illinois. Though these preglacial channels were filled and obscured by huge deposits of glacial till, and now lie buried under the Illinois prairie, they have been located during well-drilling operations. As described previously, the small Bootheel streams of early glacial times generally skirted the central portion of the Mississippi Embayment as they had since the end of the Cretaceous, following the base of the uplands on their way south.

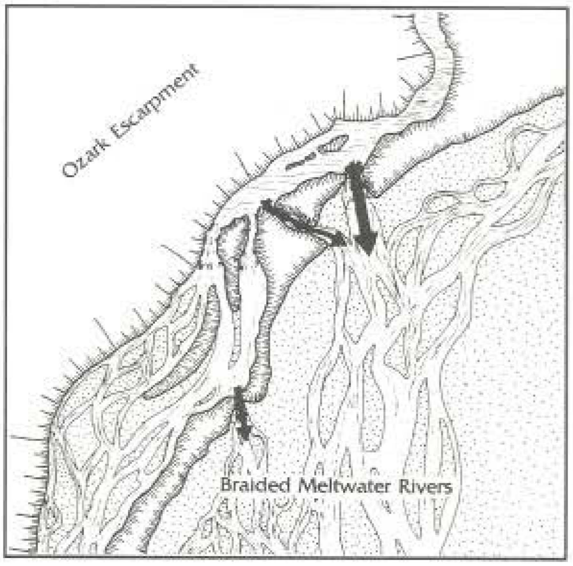
When the ice sheets formed, they blocked the original northward drainage pattern of the Ohio and Missouri rivers and forced the entire flow to the south. When melting occurred - a process that went on for thousands of years - the rampaging volume of meltwater gave birth to our modern Big River systems and Missouri's Southeastern Lowlands. Almost incalculable quantities of water reached the Bootheel from the now-combined flow of the Missouri, Mississippi, and Ohio networks. The tremendous quantities of silt, sand, and gravel swept along by the flood not only drastically altered the flood plains of the Missouri and Upper Mississippi rivers, it had even greater impact in the lowlands to the south.

The streams of the four postglacial periods cut deeply into the sediment and rock in their paths for two reasons. First and most obvious was simply the increased scouring action made possible by the huge volume of water and its abrasive bedload. Less obvious, perhaps, was the increased overall slope of the streambed as the rivers flowed to the sea. At their maximum extent, the ice sheets required a huge amount of snow and ice, and this bound up a comparably huge amount of water. This water, in the form of ice, constituted a significant percentage of the total supply of ocean water on the earth. As accumulating snow formed a glacial sheet it also lowered sea level by hundreds of feet. The gradients of the streams, and the abrasive force they were able to apply, increased in direct proportion to the degree to which sea level sank. Throughout the four periods of receding ice, the increased flow of meltwater cut the channels of the Mississippi River and its tributaries - from the Louisiana delta northward - deeper and closer to the level of the Ice Age Gulf of Mexico.

Although small and restricted at first, the expanded postglacial Mississippi in the southern tip of the Bootheel became a huge river during the summer months, the time of peak flow. In the early spring or late fall, before melting commenced in force or after it slowed, the water level dropped and the stream followed many separate channels, a twisting, uncertain pattern known as a **braided stream**. The Mississippi's wandering paths are still evident in the flood plain through Arkansas, all the way south to New Orleans. As it flowed south from Asherville, Missouri, the broad, meandering path of the glacial Mississippi swept across a flood plain over 20 miles wide. This extraordinary degree of rambling was only possible because the huge river encountered very little resistance from the loose Tertiary and Cretaceous sediments through which it flowed.

Old flood plain terraces and natural levees of the ancient river from this period show up as patches of high ground in such places as the Ash Hills, and the Dudley and Melville ridges of Stoddard and Butler counties. However, north of Asherville, the expanded volume of the Mississippi was hemmed into the ancient passage cut into Tertiary sediments and Paleozoic

Glacial Lake Girardeau overtopped Crowley's Ridge in low places and poured through, carving many new canyons and valleys.



rocks by its lethargic ancestral flow. This narrow, funnel-like entrenchment between Crowley's Ridge and the southeastern edge of the Ozarks was totally inadequate for the unprecedented amount of water that accompanied the melting of a glacier.

Nick Decker

The Mississippi River from an overlook in Trail of Tears State Park near Cape Girardeau.

Upstream from Cape Girardeau, the river passed between bluffs that were an ample 4 or 5 miles apart. From Asherville south, the river generally was able to meander through a generous flood plain over 20 miles wide. Along Crowley's Ridge, however, the giant-sized Ice Age Mississippi was forced to squeeze through what is now called the Drum Lowland. This old Mississippi flood plain lies between Hickory Ridge, Baker Hill, and the Goose Pond Hills to the southeast, and the Ozark uplift to the northeast, a scant 2 miles. The river quickly filled this channel with all sorts of debris and was forced to abandon it. The impatient river quickly cut around the low ridge and hills to the southeast, and set off through the broader Advance Lowland along Crowley's Ridge. Not surprisingly, the river immediately found itself just as tightly shut-in along this new course.

Farther downstream, near Puxico, the original Mississippi flood plain also just barely exceeded 2 miles. In addition, the river's gradient was so low in its first 50 miles southwest of Cape Girardeau that water simply could not drain away quickly enough. Even in a straight run, without meanders, the river dropped very little, perhaps only a foot or so, in each mile between Cape Girardeau and Puxico. With meanders and carrying a heavy load of sediment, the velocity of the water would have been slowed even more than normal. The delayed passage through the bottleneck at Puxico caused most of the river's bedload of gravel and sand, and much of its suspended load of silt and organic debris to settle out of the water.

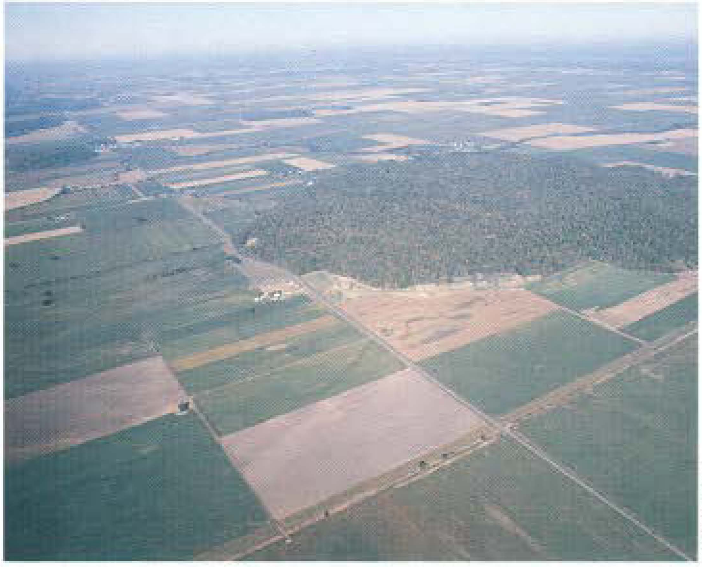
The larger, heavier pebbles dropped first, building a layer of gravel 20 feet thick directly atop the dolomite of the entrenchment. This additional sediment reduced the river's gradient, slowing its flow even more and hastening the pile-up of debris. Eventually the bed of the river in that stretch was filled until it was absolutely flat, with no gradient whatsoever. Though they are approximately 50 miles apart, the modern elevations of the old Mississippi channel at Puxico and at Cape Girardeau are now exactly the same, roughly 340 feet above sea level. This graphically illustrates the incredible degree of sedimentation that took place, and also the impossibility of ever draining the area in modern times.

The huge volume of meltwater, now essentially dammed up behind its own settled bedload, backed upstream a great distance, possibly many miles beyond Cape Girardeau itself, creating a huge lake of cold, silty glacial waters. More and more of the awesome load of water and debris, carried downstream each summer from the melting glaciers to the north, piled up in the growing lake. All of the tributary streams flowing from the Ozarks must have also backed up, much the way the Meramec is choked today when the Mississippi is in flood. More importantly, each of the many tiny creeks draining the high land of Crowley's Ridge also became ponded.

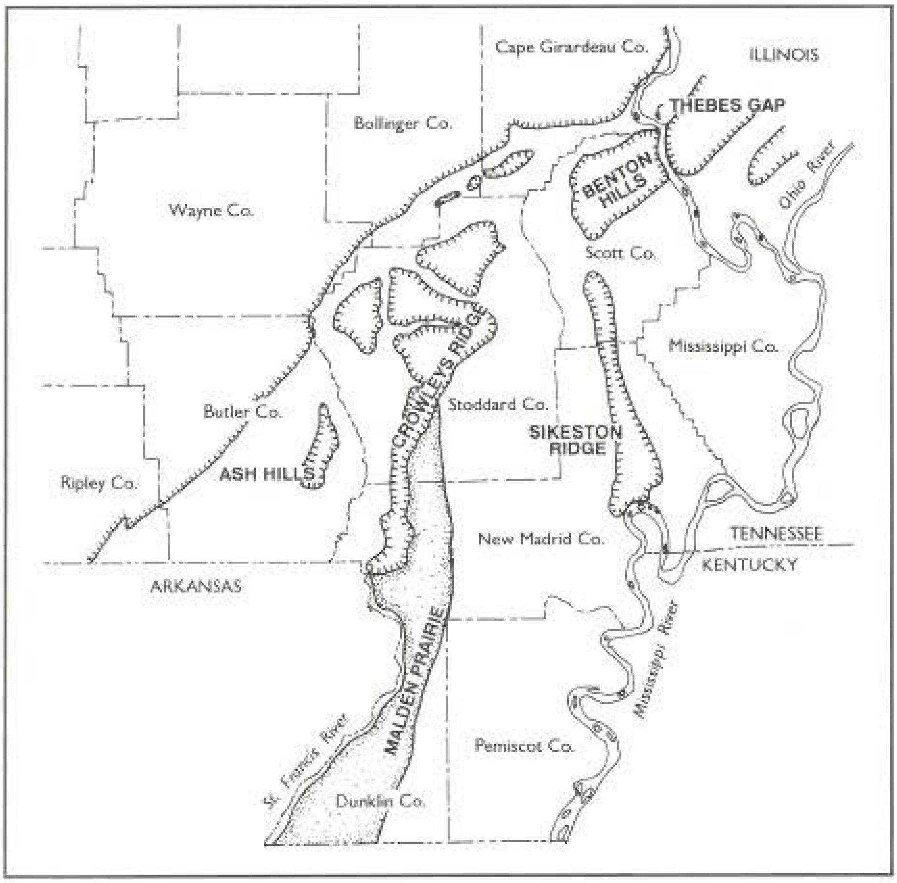
While they were able to flow into the river, these tiny streams cut deeply into the soft, fossil-bearing sediments of Crowley's Ridge and formed steep, narrow ravines and gullies. Now the rapidly expanding Mississippi lake backed up into these ravines and soon overtopped the ridge wherever it was low. Cutting quickly through the poorly cemented Tertiary and Cretaceous sands, silts, and clays, the river poured down the other side. As glacial melting continued, more and more of these new channels were cut; some became clogged and had to be side-stepped. Others intercepted resistant rocks and grew no larger.

For thousands of years, the Mississippi scoured its way through Crowley's Ridge, cutting numerous new channels and carrying off huge amounts of silt, sand, and gravel as it went. To the south of the ridge, a hundred feet of preglacial sedimentary deposits were removed from thousands of square miles of the old embayment surface. For a time one of its channels passed through the ridge north of Dudley. A later course leveled an 8-mile section of the ridge between Bell City and Oran. This course left a series of small "islands" of dolomite stuck in the flattened landscape, known today as Lost Hill, Bird Hill, Cow Hill, and Ringer Hill. Some of the river's smaller braided channels coalesced into larger passageways.

Bird Hill, near the small town of Perkins, Missouri, is one of the isolated sections of Crowley's Ridge. Lost Hill is in the left background.



Jon Hawker


Cape Girardeau Co.
ILLINOIS
THEBES GAP
Bollinger Co.
BENTON HILLS
Ohio River
Wayne Co.
Scott Co.
Mississippi Co.
CROWLEYS RIDGE
Stoddard Co.
SIKESTON RIDGE
Butler Co.
ASH HILLS
Ripley Co.
New Madrid Co.
TENNESSEE
KENTUCKY
ARKANSAS
MALDEN PRAIRIE
Mississippi River
St. Francis River
Pemiscot Co.
Dunklin Co.

The Ash Hills, Crowley's Ridge, Sikeston Ridge, Malden Prairie, and the Benton Hills are erosional remnants of an earlier landscape in the Missouri Bootheel.

As the Mississippi flowed south, still paralleling the Ohio, it meandered and flooded, but never created the kinds of habitats evident along a lowland river today. The marked disparity between summer thaw and winter freeze, when most of the flow temporarily ceased, affected the Southeastern Lowlands in much the same way that it altered the riverbed upstream, except on a much larger scale. Much of the Bootheel was barren and lifeless throughout the year. Silt blew everywhere and covered everything with loess. On Crowley's Ridge, loess accumulated to depths of 50 feet and more.

The tremendous glacial outpouring of water, gravel, sand, and silt supplied the river with the material needed to cut deeply into its bed and to build truly enormous terraces and oxbows. Among the most impressive features of the lowland landscape recalling the passage of the river at this time are the natural levees that bounded its floodway. These ancient terraces are now evident as the low north-south ridges of the **Ash Hills, Malden Prairie**, and **Sikeston Ridge**. Like giant sand shadows cast by **Crowley's Ridge**, each of these terraces lies in the protection of some part of the ridge not removed by glacial floodwaters. Like Crowley's Ridge, these are among the oldest relicts of the original embayment surface in the Bootheel. Because they were left high above the level of the surrounding flood plain, they would be the first lands in the Southeastern Lowlands to be settled and farmed by Americans.

While the meltwater Mississippi was cutting, slicing, and shifting among its various passageways through the more southerly parts of Crowley's Ridge, it also backed up another creek in the northeastern end of the ridge, in a section known as the **Benton Hills**. This low area, even though reinforced by layers of Paleozoic dolomite, was quickly breached by the dammed-up waters. The immense volume of the river poured through the rapidly enlarging break, just as the giant stream had gushed through other breaks in the ridge to the southwest. This new gap provided the most direct route south to the Ohio's enormous channel. The Mississippi gradually abandoned its other southerly channels, but remained to take advantage of this route, known today as **Thebes Gap**. Since glacial times, the Mississippi has flowed through this notch, the narrowest part of its flood plain for thousands of miles.

Now at last joined with the larger Ohio River, the Mississippi finally seemed to have found a satisfactory route to the sea, one that could manage its entire load. The ponded water of its old channel, trapped between Crowley's Ridge and the Ozarks, from Puxico back to Cape Girardeau, eventually became one of the region's largest cypress swamps. Some of the swampiest parts of that old channel are now preserved in the bounds of Mingo National Wildlife Refuge and Duck Creek State Wildlife Refuge.

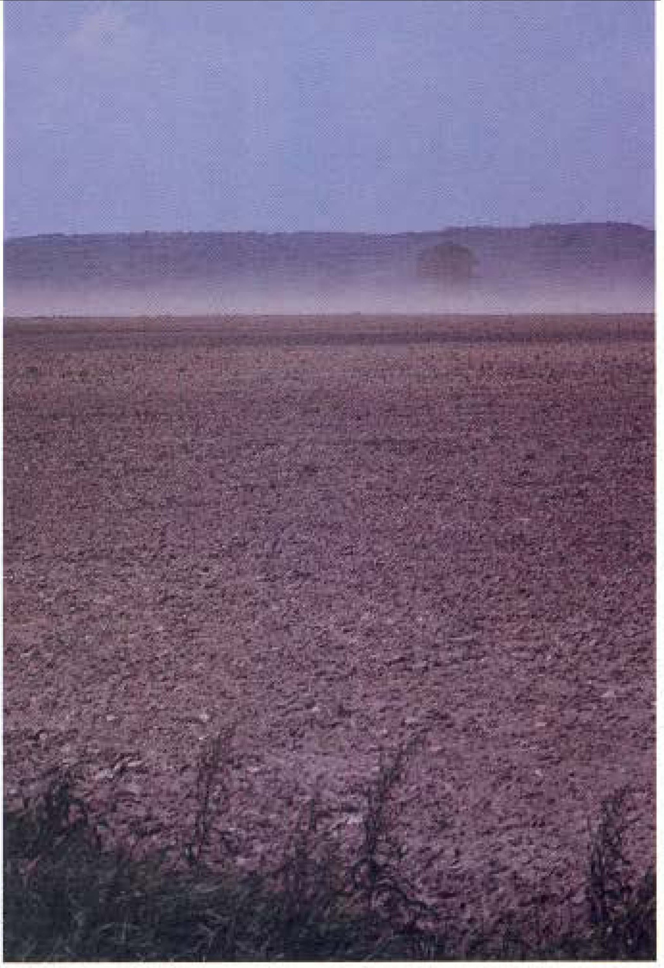
Wind-generated Lowland Landscapes

For the thousands of years it took each ice sheet to melt back sufficiently to stop overwhelming the Mississippi, Missouri, and Ohio rivers, the silt released by meltwaters and blown by the wind settled in among the trees of the highlands as loess. While it probably never accumulated swiftly enough to actually kill plants or animals - perhaps only a tiny fraction of an inch each year - the dust slowly drifted into the forests as they lived and died. Each new layer of soil was covered before it could develop very much, often sealing its contents and the layer of organic debris on its surface.

The most recent layers of loess, those from the Wisconsinan glacial stage, have preserved the shells of large numbers of land snails that inhabited the woods at the time, as well as other bits and pieces of dead plant and animal material. Consequently, the loess has much to tell us about the plant and animal communities of the day; it also has historic and economic value. Although the silty loams are not the most important agricultural soils in the Bootheel, they were among the first to be plowed.

A minor amount of alluviation can be seen after each flood along a Missouri stream, such as this new layer of sand on the bank of the Meramec River.

Jon Hawker



Jon Hawker

Dust blowing up onto Crowley's Ridge from a present-day plowed field re-creates the conditions that deposited loess on the Ridge during the Ice Ages.

In addition to the accumulation of deep layers of loess, another kind of wind-generated feature was produced at about the same time. Southwest of Poplar Bluff, nestled in the juncture of the Black River and the Ozark escarpment, one of the stranger lowland landscapes was created at the close of the Ice Age. Most of us would agree that finding sand dunes in Missouri would be a bit unusual. Finding them in the Bootheel seems to defy logic. Sand dunes are characteristic of many desert, seaside, or lakeside areas with a consistent source of dry sand exposed to a unidirectional wind. The modern Bootheel is certainly neither beach nor desert, nor are its winds predictable.

However, at the end of the glacial period the low-lying area immediately southwest of Poplar Bluff was just such a place. Because the river had been diverted far to the east, the huge volume of muddy material left in its old bed was no longer dampened by water. As the sediment dried, its silt particles were blown up onto the bluffs as loess. Too heavy to be carried aloft, the sediment's larger grains were nudged, prodded, then bounced over the abandoned channel. They soon began to pile up. The grains tumbled their way up the gently sloping face of a growing pile until they reached its apex, then careened down the steep lee side. As their loads of sand rolled along like giant conveyor belts, blowing up from the bottom, then over the top, large piles swallowed smaller ones. Sand dunes soon crept southwest over the floor of the old riverbed, parallel to the face of the Ozarks. The sharp winter winds flowing down the Mississippi Valley from the face of the retreating ice sheet provided the steady muscle necessary to move the sand and build the dunes.

After several centuries, sand dunes more than 20 feet high became a prominent feature in an otherwise featureless landscape. Although the dunes originally began well to the east of Poplar Bluff, just downstream from the site of the damming of the old Mississippi, scant evidence of their presence remains in that area. Thousands of years of erosion by the meandering St. Francis and Black rivers have since carried away nearly every trace.

To the south, near the southern border of Missouri, and extending into Clay County, Arkansas, the dunes remain well preserved, even thousands of years after their formation. With no direct assault by any of the local rivers, protected from the wind by a stabilizing cover of vegetation, and resistant to the erosive power of the rain, the piles of sand have survived. Unlike silt, which is tightly packed and easily lifted and floated by rainwater, sand is too heavy and loose. The wind-polished grains are so well-rounded and resistant to compaction that each footstep sinks and leaves a deep print in the soft sand. Rainwater sinks between the grains even more easily than feet, quickly draining away. This feature is a constant problem for farmers in the area today, because the dune surfaces tend to be extremely droughty in the absence of consistent rain.

Though drainage through the porous dunes is swift and unhampered, water has a tendency to collect underneath. When the sand first accumulated, it was piled directly on the bed of the old valley cut by the Mississippi during the late Pliocene and early Pleistocene. Dense layers of Tertiary and Cretaceous silts and clays now hinder the downward infiltration of water. As a result, water that has percolated through the sand builds up on the impervious layer beneath and appears in depressions between the dunes. The accumulation of water between the dunes creates small ponds and temporarily wet areas, called **swales**. While the dunes were stabilized by a vegetative cover adapted to dry conditions during the thousands of years since the Ice Age ended, lowland forests and swamps appeared in the ponds and swales. Today these harbor unique Missouri species such as corkwood, and one of North America's rarest plants, the pondberry.

One of the swales near the towns of Naylor and Oxly has been set aside as a Missouri natural area to protect a population of corkwood.

Jon Hawker

With the retreat of the Wisconsinan ice sheet the relative levels of ocean and streambed returned to normal. The decrease in volume and gradient considerably slowed the rivers and streams draining through the lowlands and they were no longer able to cut deeply into the older surface. Since the withdrawal of the last glacier, instead of removing large quantities of debris, the streams have been dropping most of their sediment, slowly refilling valleys and flood plains. The material laid down by these weaker rivers has filled their entrenched channels with deep layers of mud and sand. This mechanism, called **alluviation**, is a valley-filling process that continues even into the present. Alluviation is responsible for putting the finishing touches on modern flood plains.

The tremendous flooding of the Pleistocene removed nearly all traces of the earlier Tertiary landscape. The top of the bright red sands and gravels on Crowley's Ridge essentially marks the surface of the ancient Tertiary flood plain. The 100

Jerry D. Vineyard

The Missouri River in the flood of 1986 covers the entire floodplain. Such events are rare now, but were very frequent during the Ice Ages.

to 150 foot difference in elevation between that surface and the present flood plain represents the amount of material removed by the massive floods of the Ice Age. Similarly, recent alluviation and meandering have destroyed or buried most Pleistocene features. With the exception of the higher sandy terraces and levees in places like Sikeston Ridge and the Kennett-Malden Prairie, virtually all of the great changes in the landforms of the Bootheel are now masked.

It has been necessary to stress the mechanics of the Nebraskan and Kansan ice sheets because these were fundamental to much of the physical environment of northern and southeastern Missouri, and the big river flood plains: their topography, drainages, exposures, and soils. Similarly, meltwaters from the Illinoian and Wisconsinan sheets contributed significantly to modern big river flood plain and southeastern lowland formation, and their loess blankets much of Missouri, even though they never actually entered the state. Equally important, however, these last two ice sheets were critical in the final shifting about of North American plant and animal communities. The final glacial periods mixed Ozark, Great Lakes, Appalachian, and western species in the state, and contributed relict populations of boreal plants and animals.

The Pleistocene glaciers leveled northern Missouri, buried its Paleozoic surface under thick layers of till and loess, and created land suitable for modern Corn Belt agriculture. Meltwaters from the ice sheets carved the flood plains of the Big Rivers and the present surface of the Bootheel, then contributed silt that was deposited as deep layers of loess along their bluffs. Modern streams of much smaller size now meander through the great flood plains created at this time, shifting Ice Age sediments around and filling valleys scoured by the meltwaters.

Missouri's Ice-Age Plant Communities

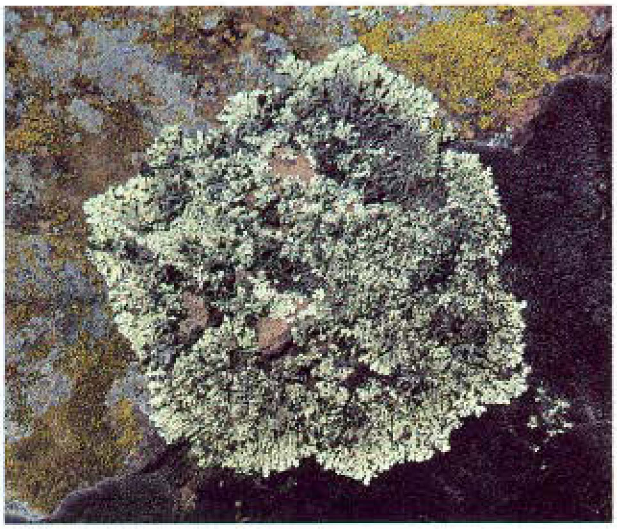
Volumes have been written in attempts to arrive at a coherent description of the communities that existed during the Pleistocene. It is a frustrating task, for the Pleistocene Epoch covers two to three million years of earth history, four principal ice advances, and four interglacials (assuming the present is probably just the most recent respite between glaciers). To give an accurate account of Ice Age habitats, it is necessary to distinguish between the plants and animals of the cooling and the warming trends, to explain how those mixtures responded to a changing climate, and then to describe how the species composition was further altered as evolution proceeded. A complete picture is simply not possible in this book, but a brief synopsis is critical to understanding how Missouri has acquired so many different plants and animals, and how the region came to be the way it is.

It is probably fairly easy to imagine why Arctic and boreal species must have moved into our area during each glacial period, then retreated back north with the melting ice. After all, it has to be tough trying to make a living underneath or on top of 2,500 feet of ice! And for most Arctic species, our present-day Missouri climate would certainly be a drag. Yet, people sometimes picture animals fleeing in terror before a crushing ice sheet, and then wonder how it could have been possible for the plants to have escaped at all. Actually, no such flights of panic were ever necessary.

Whether advancing or retreating, an ice sheet requires thousands of years to reach its full extent or withdraw entirely. Clearly, if the life expectancy of an average generic tree is 100 to 400 years, a dozen generations of forest will live and die before the community can be ousted by a slow, rumbling glacier. As the climate becomes chilled, century by century, the seeds and sprouts of a forest will survive less well along the northern fringes of its range. In contrast, the trees' reproductive success is enhanced to the south, especially as competition with more southerly species declines; these southern competitors are also feeling the effects of climatic change and similarly fail to propagate along their northern limits.

Each biome slowly migrates southward away from the advancing ice as succeeding generations creep a little farther into territory formerly held by southern neighbors. It is not necessary for a single individual plant or animal to move an inch. Preserved as intact bands of vegetation, complete with all species of dependent animals, the zones shift southward with each ice advance, then back as the climate warms.

The Mississippi was a major element in these glacial retreats and postglacial recoveries. In Europe, the Ice Ages brought the same kinds of changes to the land and its inhabitants as are recognizable here. The advancing ice "pushed" the temperate deciduous forest ahead of it, just as it did here in North America. In Europe, however, no major rivers drain southward and the escape route to southern refuges, called **refugia** by ecologists, was blocked by the high Pyrenees and Alps. Trapped, most of the vegetation perished, an event reflected today by the much lower species diversity of European forests. While Europe has no shortage of cold-loving coniferous trees, species that could easily survive the climatic stress, there are far fewer warm-temperate deciduous species than in North American forests. North American forests had easy escape and return routes, European species did not. Actually, "easy" is a very relative term, since some American trees only reached the present northern limits of their ranges in New England about 2,000 years ago, centuries after the last glacier melted back.


Jerry D. Vineyard

Patches of lichens color a sandstone glade in western Missouri.

The north-south distribution pattern of Pleistocene biomes was probably very similar to that which can be seen on a map today, although the actual area of land each covered was undoubtedly much smaller. Like the letters painted on a balloon that is alternately inflated and deflated, the communities must have displayed amazing elasticity as glacials and interglacials came and went. North-south ranges would have been very compressed during an advance. As their northernmost limits were forced to withdraw hundreds of miles before the ice, all biomes would have been squeezed into those ice-free zones that remained on the continent. Comparable movement to the south was held in check by the shores of the Gulf of Mexico. Although the coastline expanded slightly as Ice Age sea levels dropped, it did not provide an area equal to that which was buried by ice. At full ice expanse, Nebraskan- and Kansan-age Missouri were both the home of narrow strips of several biome types - a little bit of tundra, a broad band of boreal or evergreen forest, and in the extreme southern Ozarks and along warmer river bluffs, whatever leftover deciduous forest species could manage the cold.

Jon Hawker

Once the ice retreated the scoured surface of northern Missouri would have been flat and boggy with many small ponds and lakes.

As the ice retreated, exposing the soggy glacial till, the hardiest of northern plants moved in right behind it. Lichens, mosses, and soil-hugging herbs reclaimed higher, better-drained patches of ground from the ice, soon creating a lush mat of vegetation on the rich materials of the fresh drift. This plant community, called tundra, is characteristic of mountaintops above treeline and the high Arctic, such as the North Slope of Alaska, and seldom grows more than 1 to 6 inches high. Walking the tundra of the Arctic National Wildlife Refuge today is a hike through time back to the post-Nebraskan and post-Kansan periods of northern Missouri. There would have been few differences.

On mounds of sandy soil, tight cushions of milkvetch, moss campion, and phlox only an inch high captured the heat of the sun and stingily kept moisture away from the drying wind. Between the mounds, where water might collect for a time, a dense sod of sedges, buttercups, poppies, dwarf forget-me-nots, spring beauties, clovers, asters, violets, knotweed, and shooting stars only 2 inches tall covered the finer, siltier soils.

As the ice retreated, a thick carpet of bright tundra wildflowers followed, including poppies, spring beauties, and violets.

Jon Hawker

Hamster-like lemmings, voles, and other related meadow mice burrowed through this dense turf, their strong incisors cutting trails with machete-like precision. As is true today, small plant-eaters outnumbered the larger, more impressive tundra grazers of the Pleistocene. The principal herbivores of the tundra, lemmings, feed and breed prodigiously. It is not unusual for their numbers to increase 100-fold in the course of a single season. At times, 1,000 lemmings may be found on a single acre, although 400 would be considered an average peak. Winters are hard on the little rodents, however, and their numbers often crash to near zero as suddenly as they swell.

Jon Hawker

Tundra animals, such as the snowshoe hare, musk ox, and ground squirrel would have moved, cropping the rich carpet of vegetation.

Mounds of well-drained soil and dry banks spawned populations of ground squirrels seeking refuge from Arctic foxes, wolves, and bears. Their burrows undermined the sod of the new till and littered its surface with craters and tiny spoil banks. At times small herds of snowshoe hares scrambled chaotically over the short grass and herbs, occasionally taking two or three upright bounces on pogostick hind legs to peer back at a threatening predator. Clouds of warbleflies, blackflies, and mosquitoes bred in and hummed over this wet carpet, plaguing Ice Age beasts every bit as much as they harass tundra animals today. The water in every puddle and bog was a living soup of their larvae, each sip rich with wriggling protein in fuzzy black costumes. In all probability, these pesky biting flies could only attack the eyes, ears, lips, and snouts of the wooly mammoth, the largest grazer of the Pleistocene tundra, one of the really obvious differences between tundra today and then. Standing 12 to 15 feet high at the shoulder, the hairy Jefferson's mammoth, the most common species found in the Midwest during the Pleistocene, used its 10-foot tusks to scrape the crust of snow and ice from atop its winter forage. Its 10 to 15 inch coat of hair and underfur undoubtedly saved it from much of the warble fly and mosquito attack experienced by caribou and musk ox. The chief motivators of roving caribou herds on tundra today, bloodsucking mosquitoes and egg-laying warble flies also constantly harassed Ice Age grazers, keeping them on the move, face-first into the wind, the only sensible summer migration pattern.

After years, perhaps centuries of nothing but soft-stemmed or herbaceous growth, the snaking woody stems and tiny, leathery leaves of Arctic willow and mountain dryad might bind yard after yard of the soft drift under a serpentine mesh dotted with creamy blossoms or fuzzy clusters of seeds, like lost rabbit's tails. Between the lowest hummocks, the drowned soils could not have supported such species, but were still dominated by mosses, water-tolerant sedges and grasses, and possibly a few bright clumps of marsh marigold. In time, and with continued warming, some of the moisture-loving woody plants of the taiga - the broad zone of twisted, elfin black spruce that separates treeless tundra from the fully developed coniferous forest farther south - overtopped the herbaceous species in the boggy depressions. Among

Snowshoe hare

Jon Hawker

Jon Hawker

In time, a stunted forest, called taiga, covered the land, replacing the tundra with spruce and other trees.

these were bog rosemary, stunted black spruce, tamarack, alder, and cranberry.

With initial warming early in an interglacial, the narrow band of tundra and taiga soon became stressed. Accustomed to long winters and short, cool summers at the edge of the ice sheet, these communities were not suited to the gradual change in climate. As the tundra abandoned its southernmost territories, boreal vegetation began a return trip that would take thousands of years. From the northernmost sloughs, hills, and valleys of the Ozarks, seeds and spores of this Canadian forest were carried everywhere by animals or the wind.

To the north, on the lands so recently buried by ice and now covered by tundra, the shower of propagules would find favorable conditions developing. Low-growing swamps of black spruce, white cedar, balsam fir, tamarack or larch, and black ash, well-suited to the acid, tea-colored water that had resulted from centuries of accumulating organic matter, crept in among the stressed and dying tundra communities. Similar spongy, water-logged bogs still develop along streams, around lakes, and in old ponds of the north. Then and now, bogs share a distinctive group of species.

A mat of bright, yellowish-green sphagnum moss, dotted with short pitcher plants, bog rosemary, bog-bean, and small orchids, draped watery spaces among the trees wherever light was available. Mud minnows, four-toed salamanders, wood frogs, and bog lemmings were among the tiny handful of animals that could make a living in such a sterile environment. Spongy layers of needles, leaves, cones, bark, and twigs eventually buried everything, adding their humic acids to the already sour water. Other bogs were taken over by dense, floating mats of cattails, bulrushes, and sedges, sometimes supporting a few scraggly and trembling clumps of white-berried poison sumac.

The taiga bog species, now no longer able to successfully reproduce or compete in the lengthening and warming summers, reluctantly gave way over a period that lasted many centuries; however, some of these boreal bog-dwelling plants and animals seem to have been more reluctant to leave than others. Even today, a few still linger in the Ozarks.

Small populations of wood frogs remain in Missouri centuries after their primary habitat retreated far to the north.

Jon Hawker

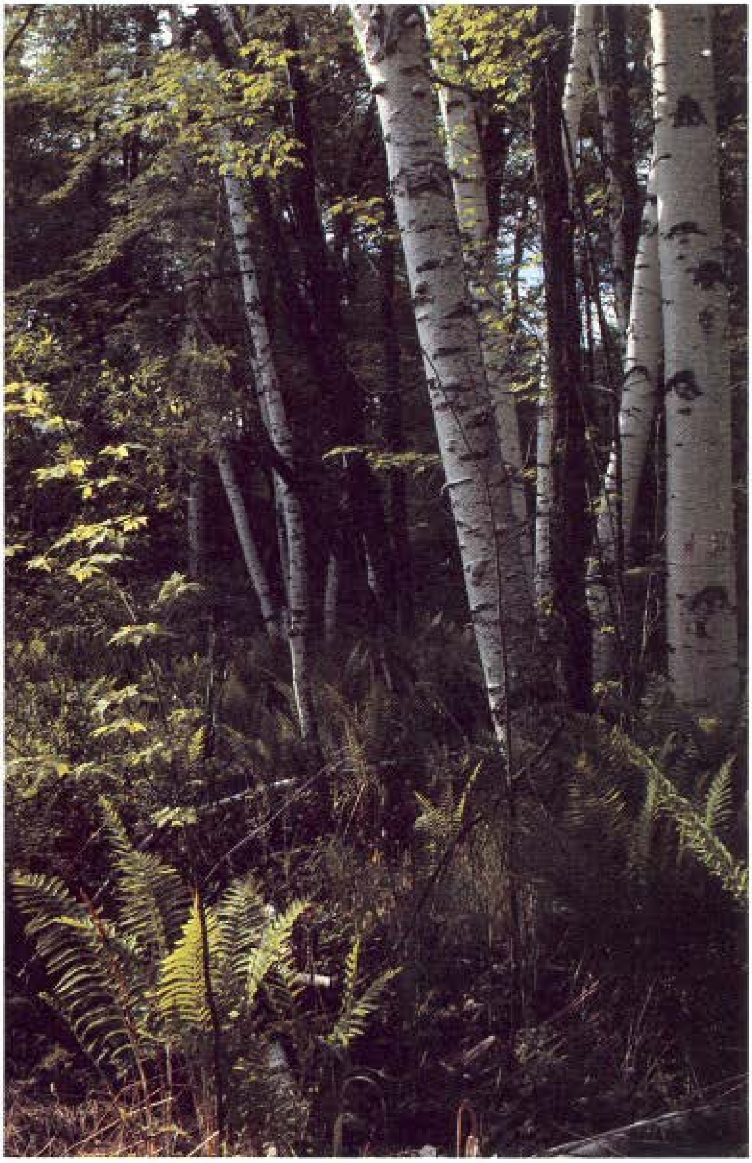
Each time the string of biomes marched back north, it was inevitable that some species would prove more resilient than others to the changing climate. Others would find refuges in small, well-protected nooks where local conditions remained relatively moderate. A number of northern bog and marsh species - including bog bean, two species of sedge, Loesel's twayblade and snakemouth orchids, queen of the prairie, marsh blue violet, swamp wood betony, marsh bellflower, Riddell's goldenrod, and glossy-leaf aster - were able to cling to the cool, moist soils of seeps along Ozark streams. Thousands of years after their cohorts abandoned the state, these still linger in such locations, separated by hundreds of miles from their relatives far to the north. Now cut off or disjunct from the main body of their population, these species represent what are known as **relict populations**. Like the weathered relicts of a ghost town, these plants are the relicts of a former more widespread distribution pattern of species that once occupied the area.

Jon Hawker

Many boreal plants, such as this red-berried elder, remained in Missouri as relict populations, while most of their companions followed the ice back to the north.

Like bogs, better-drained boreal forest communities would also leave some stragglers behind as biomes fled northward. Four species of club mosses, ostrich and hay-scented ferns, wild leek, white camas, starry false Solomon's seal, cucumber-root, grove sandwort, white anemone, purple cress, northern bedstraw, meadow sweet, plain rose and Virginia rose, amethyst shooting star, Sullivant's milkweed, American barberry, partridge berry, false bugbane, rose turtlehead, harebell, barren strawberry, kidney-leaf sullivantia, heartleaf golden ragwort, poor ragwort, white lettuce, nannyberry, arrow-wood and downy arrow-wood, red-berried elder, wolfberry, meadow willow, quaking aspen, choke cherry, black maple, red ash, Hill's oak, and rock elm - all remain in Missouri today to represent their missing northern forest and give witness to a former more southerly distribution pattern.

A few of these species are found along the hilltop prairies and riverbanks of northern Missouri, but most grow along cool, shady bluffs where conditions are even more like "home." One group is associated with moist Lamotte, St. Peter, and Roubidoux sandstone bluffs in the Ozarks. Another thrives on the rich soils of the Mississippi River bluffs from Hannibal, through Louisiana, as far south as Elsberry. This last group of hills - known as the Lincoln Hills for its Lincoln County location - is especially notable because they seem not to have been scraped by either Nebraskan or Kansan ice. As islands of unglaciated land surrounded by a sea of ice, they have earned the name **nunataks**. "Nunatak" is an Inuit or Eskimo word that originally referred to the isolated tips of mountains that poked through the vast Greenland ice cap. The term has been adopted by geologists to describe similarly-exposed mountaintops in Greenland, Antarctica, and elsewhere. It may be appropriate for the Lincoln Hills as well. While most of our boreal forest species are fairly common and widespread throughout the glaciated region of the state, some of the rarest exist only as relict populations on what might have been nunataks 500,000 to a million years ago.


Jon Hawker

Eventually deciduous trees, including oaks and birch, moved in among the conifers.

Continuing our hike through time on the Missouri tundra of those long-ago periods, we would see that on soils which were better drained the luxuriant mats of lichens, mosses, and forbs were being overcome by a persistent invasion of a drier type of boreal forest. This pioneering forest was not particularly rich in species, consisting largely of white spruce, paper birch, and balsam fir. Soon thereafter, however, a mix of red pine, white pine, paper birch, bigtooth aspen, quaking aspen, northern red oak, and red maple would augment and supplant these earliest woody invaders. A rich understory, including highbush cranberry, round-leaved dogwood, thimbleberry, red baneberry, and nodding trillium would push out the last of the low, sun-loving tundra fugitives. The driest sites, the droughty soils of sandy knolls, were now populated by jack pine and northern pin oak (also known as Hill's or jack oak), with a coarse screen of low blueberries and bracken fern completely shielding the ground.

In Ice Age forests, from the edge of the ice as far south as Florida and Mexico, the mastodon was the most impressive browser. A version of ancient American elephant smaller than the mammoth, the mastodon's relatively streamlined body and conservative tusks allowed access to the leaves and twigs of the deepest tangles of taiga and deciduous forest. Perhaps Missouri's most famous mastodons were unearthed in 1979 and 1980, near Kimmswick in Jefferson County. Their giant bones, along with those of other forest dwellers of the day,

Dave Hoffman

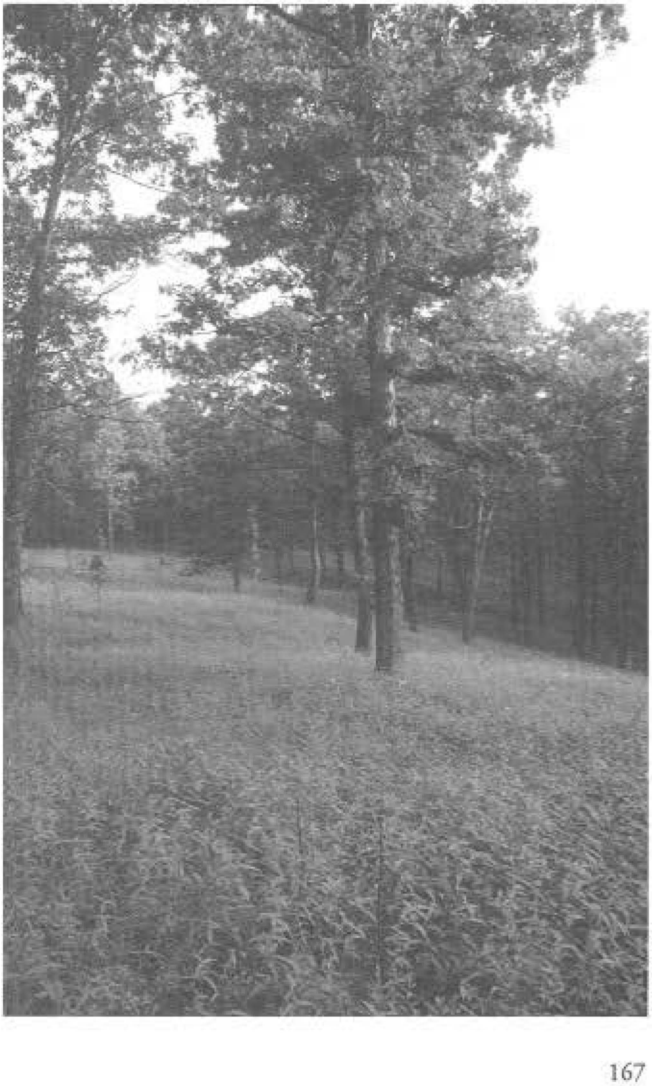
Dewatering and subsequent excavation, here shown in progress, of spring bogs in the Pomme de Terre River valley near Warsaw yielded a treasure trove of mastodon bones. The vertical pipes are well casings used to dewater the boggy, spring-fed sites that trapped the heavy animals.

such as the stag moose and long-nosed peccary, were found in close association with stone tools and projectile points left by Missouri's earliest known human inhabitants. Of great archaeological significance, the site is now part of Mastodon State Park.

As the shallow marshes and swamps that covered northern Missouri continued to fill with slowly decaying organic matter, an intricate network of invading forest wound its way through the maze of wetlands. In orderly succession, the aquatic species of bog and swamp gave way to vegetation with terrestrial inclinations. Ordinarily, the sphagnum bogs, cattail marshes, and cedar swamps yielded eventually to dense forests of sugar maple, basswood, yellow birch, and hemlock. Occasionally, however, wet grasslands, dominated by cordgrass and ringed by willow, were able to overrun some of the shallower bogs. This event would have been especially likely if fire intervened during one of the periodic postglacial droughts. Fires increased as interglacials progressed because postglacial climates were generally accompanied by diminished rainfall. Such fires - and the droughts that spawned them - obviously retarded the growth of forest.

As these occasional fires spread, they would have had greater impact on the drier patches of woods on elevated soils, killing the shade-producing trees and opening the soil to the seeds of jack pine. A supreme colonizer of burned-over land, jack pine evolved a lifestyle designed to take advantage of such fires. Roughly half its cones remain on the tree after maturing, sometimes for as long as 25 years. The cones remain tightly shut the whole time, but open quickly with exposure to heat. The resin sealing a jack pine cone softens at 116°F, so even the low flames of a very minor ground fire are sufficient to release the seeds. The seeds within are resistant - for brief periods - to temperatures that might actually ignite the cone itself. As a result, scruffy jack pine forest became a common, but temporary feature of the drying postglacial landscape.

Temporary, because jack pine matures quickly and is soon overtaken by other forest species. Yet the species always manages to find enough new, recently exposed sites to sustain itself. Under natural conditions, fires seem to occur just often enough to renew populations of such fugitive species, those always on the run looking for unclaimed soil. Even so, fire had not yet assumed the degree of significance to North American ecology that it would in the millennia to come. Its importance as creator and destroyer of habitats would not peak until the end of the Ice Age and the arrival of humans. In the first two Pleistocene interglacials, lightning-caused fire was the chief means by which plants and animals were shifted about in upland communities.



A savanna is created when fire sweeps across the forest floor, removing woody undergrowth, but encouraging the growth of grasses and wildflowers.

Jon Hawker

As the climate warmed, and as an expanding drainage pattern cut into the soft till, many parts of wet northern Missouri were drained and dried. Drying enhances warming. This stressed the remnants of boreal forest even more and allowed members of the southern forest to infiltrate the northerly mix. At first, these forests of white oak, walnut, hickory, hackberry, black cherry, and others, commonly found throughout Missouri today, might only have been able to push onto the warmest southern exposures. Of course, the trees would have been accompanied by a complete contingent of southern shrubs and wildflowers. Like the scouts of an invading army, small "islands" of Ozark vegetation appeared among the retreating northern forest.

As the warmest periods of an interglacial settled in on the North American continent, fires occurred with greater regularity. Western prairies expanded a bit farther east and north with each dry spell and each subsequent blaze. Pushed by strong winds - now more often from the southwest and west than at the peak of a glacial - the flames spread easily from established grassland, across flat, open terrain, through old, dried marshes, and deep into forests littered with dead

Jon Hawker

The remains of plants buried by glacial silt thousands of years ago lie exposed along Coldwater Creek in St. Louis County.

branches, needles, and duff. The fires killed indiscriminately; but some trees proved more resistant than others. Selection by fire produced thin stands of trees with much open sky and an abundance of sunlight, called **savannas**. Grasses and sun-loving wildflowers replace the normal forest undergrowth in such open communities, creating a parklike appearance. Similar savannas - now regularly burned by park personnel to maintain their natural appearance - can be seen at Ha Ha Tonka, Hawn, Cuivre River, or Montauk State Parks.

The strategy of the dominant trees in these warm-temperate savannas differs somewhat from that of the cold-temperate jack pine. While the pine dies and replenishes with new seeds, the bur oak and bitternut simply endure a passing fire, hardly giving it a moment's notice. Once they are a decade old or so, their saplings are largely immune to a low grass fire, provided it passes swiftly enough. After these oaks reach middle-age they are completely oblivious to the flames. As the warming interglacial climate climbed its temperature peak, fire also reached its peak of opportunity and importance. In turn, the thick bark of bur oak and bitternut hickory gave considerable fire-resistance, and a unique measure of status all their own. They became the forest colonizers of expanding warm grasslands.

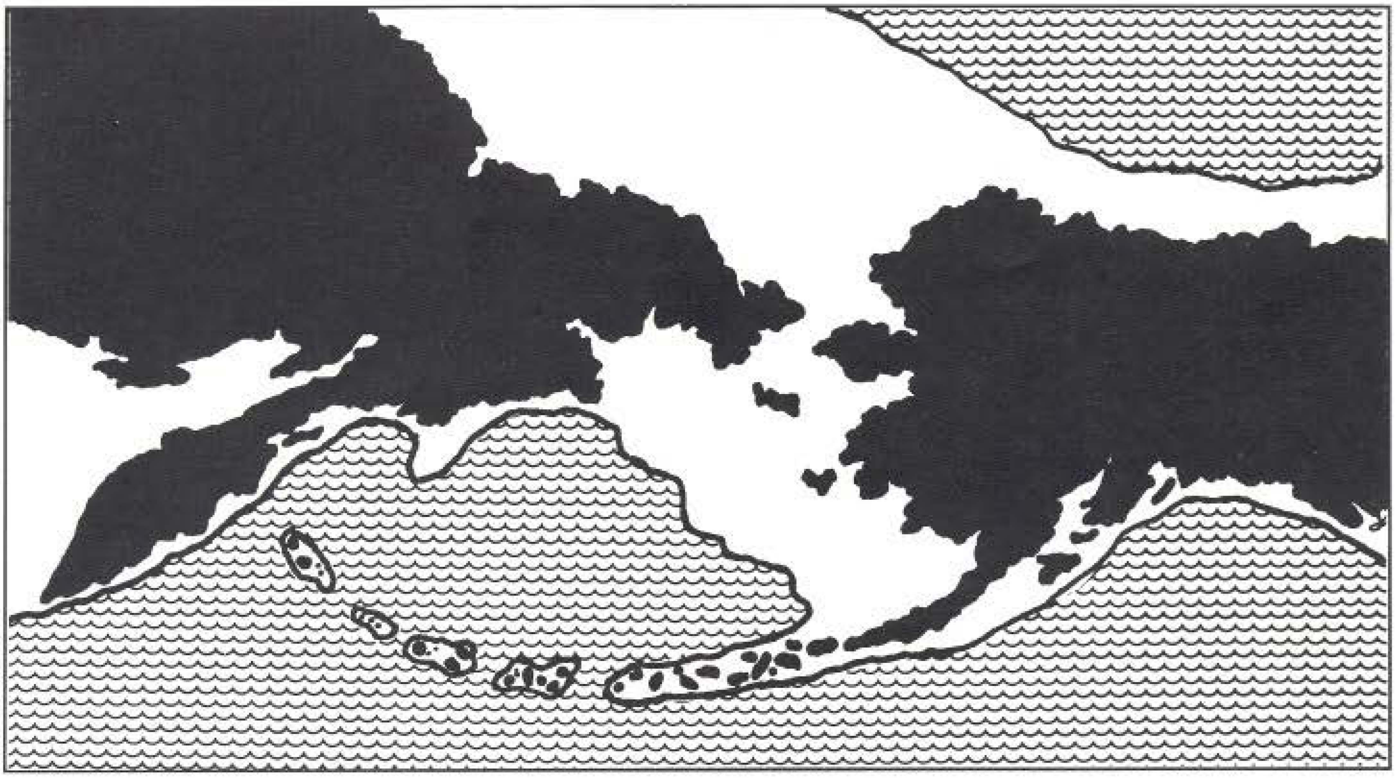
Broad tracts of grassland - perhaps the first true prairies to occupy Missouri - developed as dry conditions became more commonplace. Forest, savanna, and prairie battled for positions along constantly-shifting "skirmish lines" that lasted for thousands of years, until the next glacier advanced into the Midwest. With that advance, southern species once again fled in orderly succession and were replaced by boreal and tundra species. With some modification due to evolution and extinction, and to differing degrees, this same cycle of shifting climates and biomes was repeated four times in Missouri. The process eventually resulted in the best-drained, richest soils northern Missouri has possessed in more than two million years, as well as remnants of the forests, prairies, and savannas that covered them during the period.

The reader may wonder how it has been possible to describe the orderly passage of biomes during the Pleistocene using modern plant names, especially when some of the animals mentioned - like mammoths and mastodons - have now passed into extinction. Weren't the plants also different back then? Basically, no. Plants do not seem to have evolved greatly in the past one or two million years. Some animals, such as mollusks, fish, and reptiles, also seem to have changed little during or since the Pleistocene. Most fossil specimens of plants, mollusks, and cold-blooded vertebrates from the Ice Ages have remarkably similar, often indistinguishable living counterparts. In contrast, the mammals and birds underwent rapid and radical change during the same period. Many new forms arose and an enormous number passed into extinction; thus, it is far more complicated to describe Pleistocene communities in terms of their dominant animals.

Missouri's Ice-Age Animals

During the Nebraskan Glacial and the Aftonian Interglacial that followed, the mammalian fauna of Missouri was a mix of many strange and only a few familiar species. A large number were species endemic to North America, but some were recent arrivals. A few of these newcomers, like the 'possum, armadillo, and giant ground sloth, had managed to migrate across the Panamanian land bridge formed in the Pliocene. However, a growing number were arriving from Asia across a sometime thing called **Beringia**, the Bering land bridge.

Each glacial sheet that developed was composed entirely of compacted and recrystallized snow, snow derived from water vapor that had originally been withdrawn from the oceans. Consequently, each huge ice sheet tied up an awesome amount of ocean water and lowered the level of the seas by as much as 200 or 300 feet. Even if it lowered the oceans as little as 180 feet, the Chukchi Sea, the Bering Strait, Norton Sound, indeed, much of the northeastern part of the Bering Sea, would all be dry land. With each glacial advance, for 100,000 years at a time, a dry land bridge between 400 and 1,500 miles wide was exposed between the two continents. Because Eurasia and North America are climatically similar, this recurrent connection has actually been far more influential in determining the present species



When glacial ice sheets were at their maximum extent, lowered sea levels allowed plants and animals to cross a temporary land bridge between Siberia and Alaska (in black), called Beringia (in white).

mix of Missouri than the more permanent Central American land bridge that formed millions of years earlier.

Even though Beringia was near and even north of the Arctic Circle, the climate along its southern half was not as extreme as one might think. Having cut off the flow of cold Arctic ocean water, and much of the Arctic air that now chills southern Alaska, the Bering land bridge insulated the northern Pacific. The surging Japan current - that even now warms British Columbia and the Alaskan panhandle - had a much greater impact on coastal lands. From Manchuria to California, all regions near the Pacific had remarkably mild and uniform climates. Across the length of Beringia, in horizontal bands from north to south, permanent snow and ice, tundra, boreal forest, grassland, and wet coastal forest permitted the entire spectrum of Asiatic and North American plants and animals access to the other continent. Thus, the great ice sheets did not bar the movement of plants and animals across this northern route; their effects actually encouraged migration.

The Eurasian shrew and mole families; the skunks, mink, weasels and martens; the bears, otters, and deer all gained access to Missouri via Beringia. Undoubtedly these immigrants wandered right past members of some native North American groups, such as camels, horses, and raccoons, as they migrated westward into Asia. For some reason, neither the gigantic wooly rhinoceroses of Eurasia nor the nimble pronghorns of North America took advantage of the Bering land bridge. Some settlers died out soon after immigrating. Others succeeded while their home-bound ancestors perished. Once settled in Asia, for instance, horses and camels subsequently died out in North America, only to be reintroduced by humans thousands of years later. In fact, humans themselves arrived in North America during the Pleistocene by exactly the same route as other Eurasian species.

The convenient Bering Strait land bridge appeared each time a continental glacier advanced, permitting yet another shuffling of species. Yet by the time the Illinoian sheet faded back to Canada, much of our present Missouri fauna was already in place. Mink, badger, otter, striped and spotted skunks, coyote, gray wolf, gray fox, red fox, black bear, white-tailed deer, and elk are some of the recognizably modern species of Eurasian descent that inhabited Missouri landscapes in this as well as the previous interglacial. During the Illinoian and Wisconsinan glacials the region provided a home for a temporary invasion of caribou, musk-ox, moose, snowshoe hares, lemmings, ground squirrels, snowy owls, and the rest of the tundra and boreal contingent. The modern mix of Missouri mammals was only finalized about 4,000 years ago when the last of the old Pleistocene mammals expired and modern northern species retreated.

Jon Hawker

Elk, or wapiti, such as these in St. Louis County's Lone Elk Park, migrated into North America along with other members of the deer family.

Was The Pleistocene Just Mastodons?

Like the plants, the animals occupying Missouri would also have had to adjust to the advancing and retreating glaciers. Most descriptions of the animals of the Pleistocene usually focus on one particular group, the mammals, and for a very good reason. The end of the period referred to as the Pleistocene can also be used to mark the end of what has been called the Age of Mammals. As prevalent as mammals seem today, their dominion over the earth was far greater two million years ago. Somehow the Tertiary dominance of mammals was badly shaken during the period of glaciation.

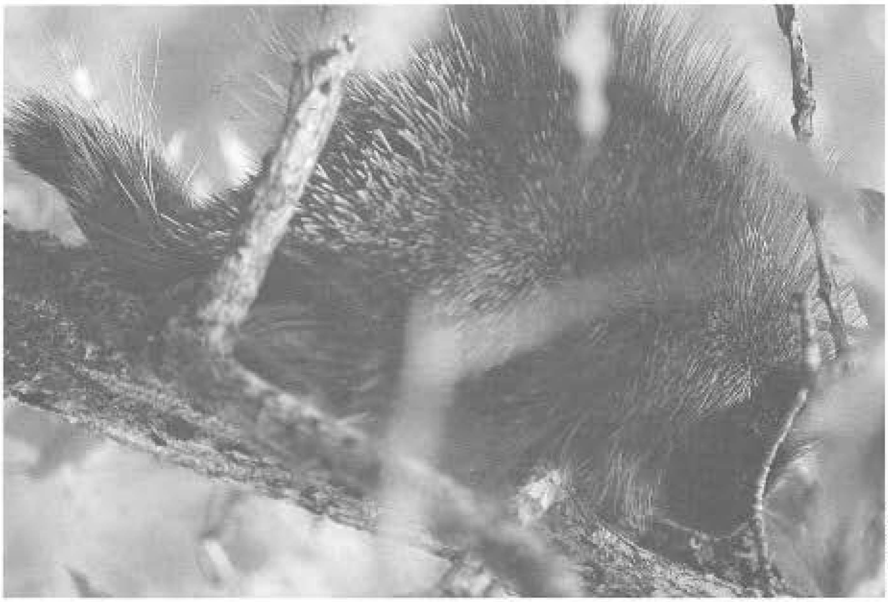
In response to the cooling climate of the Pleistocene, bulk seems to have become an important survival mechanism among mammals. Generally speaking, a large animal, with its relatively small surface area and large mass, loses heat more slowly than a tiny animal. The reduction in heat loss conserves energy. Thus, birds, shrews, and mice have extremely high metabolic rates to maintain their body temperatures, and correspondingly high rates of food intake. They eat a lot. If one truly "ate like a bird," one would be as big as a house in no time.

If this same size-surface area rule can be applied to the fauna of the glacial epoch, then some ice-age mammals must have lost very little heat indeed. The phrase "big game" takes on a totally different meaning when discussing Pleistocene mammals, often referred to as the "megafauna." These were far and away the biggest and weirdest group of fur-bearers that ever fed in Missouri forest and field.

Those impressive 20-foot ground sloths and 9-foot, armadillo-like glyptodonts discussed much earlier were not so unusual back in the Ice Ages. There were also giant beavers 4 feet high at the shoulder; actual elephants, and their well-known cousins, the mastodons and mammoths; huge versions of bison and musk ox; recognizable horses, camels, elk and deer; giant American lions and saber-toothed cats; the dire wolf, enormous short-faced and cave bears; flat-headed peccaries and tapirs; and finally, people, who among terrestrial animals living today, are still in the top 0.5% in size.

While most of these enormous and sometimes peculiar creatures are now extinct, their remains - some fossilized and some preserved nearly intact in Arctic ice or in dry desert caves - spark the imagination for contemporary paleontologists, just as they did for Thomas Jefferson. The odd bit of fur or fragment of bone gives a glimpse of the strange forms life had taken by the time humans arrived in North America toward the end of the glacial epoch.

While there is a tendency to focus on the unusual, or the large and spectacular, small animals like lemmings, ground squirrels, and Arctic hares mingling cautiously with the megafauna, were far more common then, just as they are now. Many familiar insect-eating mammals, including most bats, the least shrew, masked shrew, short-tailed shrew, and eastern mole were already in a recognizably modern form at the beginning of the Pleistocene, nearly 1.5 million years ago. A Missouri contemporary of these wide-ranging species, the endemic Ozark short-tailed shrew, was evidently not destined for ultimate success and passed to its reward long before the Ice Ages ended.



Jon Hawker

The plump, but well-defended porcupine, was a favorite prey of the diluvial fisher in Ice Age Missouri. Neither are found in the state today.

Like other animal groups, the shrews and moles of the boreal forest, members of the order of insect-eating mammals, thrived in this part of the world as long as conditions were favorable, but retreated when the habitat in their adopted latitude deteriorated. The Arctic shrew, for instance, has been a resident of Missouri during each of the ice advances, but has always returned north with the tundra. Similarly, the hairy-tailed mole accompanied the cool forests back to the northeast. The range of the bizarre-looking and semi-aquatic star-nosed mole also shrank to the east when the wet, marshy interglacial habitats of Missouri dried out. The comparatively warm, arid climate since the close of the Wisconsinan forced these little predators to yield to more resilient species.

Among the animals that people find most interesting is the order of carnivorous mammals. This group of predominantly meat-eating mammals includes a wide variety of closely related families, among which are the bears, dogs, cats, raccoons, and weasels. This last group includes the smallest members of the order, and in the Pleistocene three kinds of weasels occupied Missouri.

The least weasel, only recently rediscovered in Missouri, was the smallest of the small carnivores. Perhaps it has returned simply to regain the title. During the later stages of the Pleistocene, this nervous little bundle of energy dealt murderously with mice at least as far south as Arkansas. Its larger relative, the long-tailed weasel has been around longer than any other, with a fossil record going back into the Pliocene. The long-tailed weasel was always one of the most widespread members of its clan, and today it is the only common weasel in Missouri. The third species, the short-tailed weasel, only entered the state during the later ice advances and is now restricted to northern coniferous forests.

In Nebraskan-age Missouri, a now-extinct weasel relative called the diluvial fisher filled the same niche as the fisher of today's northern boreal forests. Since late in the Pleistocene, the incredibly acrobatic fisher has chased and caught chickarees in swaying treetops 50 feet off the ground. Just a tad larger than our chipmunk, the chickaree is the agile, arboreal red squirrel of northern and montane coniferous forests.

The rodent chatters constantly from low branches and nibbles the daylights out of pine, spruce, and fir cones, littering the forest floor with huge mounds of dismembered bracts. Fishers are also fond of the fatty flesh of porcupines and are unbelievably adept at flipping the large rodents over without being impaled in the process. A couple of stained bones, some scraps of skin, and a few tufts of soft hair bristling with black and white spines are all that will remain of an unfortunate porcupine that stumbles into the path of a hungry fisher. Fisher, chickaree, and porcupine were inhabitants of our Ice Age forests, but are not found in Missouri today.

Unfortunately, very little physical evidence is available to indicate what might have been happening to non-mammals; to butterflies, grasshoppers and spiders; to millipedes, daddy-longlegs and worms; or to a host of other small animals. Such soft-bodied creatures seldom leave fossil remains. Likewise, the thin, delicate bones of birds, fish, and amphibians are rarely deposited in places that allow them to be preserved. The fossil record of such tiny creatures is largely a mystery, not only because the preservation of such materials is uncommon, but also because early researchers often unintentionally destroyed much material that they considered inconsequential as they hurriedly dug for more impressive mastodon and mammoth remains. Today's archaeologists and paleontologists are much more systematic in their excavating. As a result, modern digs are revealing far more about glacial environments and their tiny, obscure inhabitants, as well as their giants.

Fortunately, one invertebrate group has left bountiful artifacts to help enlighten us. The well-preserved shells of snails and clams give valuable clues, at least to the sequence of migrations during the most recent glacial and interglacial periods. Buried in the deposits of riverside bluffs, in old marshy tracts bordering Ice Age streams, and in the midden heaps of the earliest Indian cultures, mollusk shells help trace the southward migration and the return trip north.

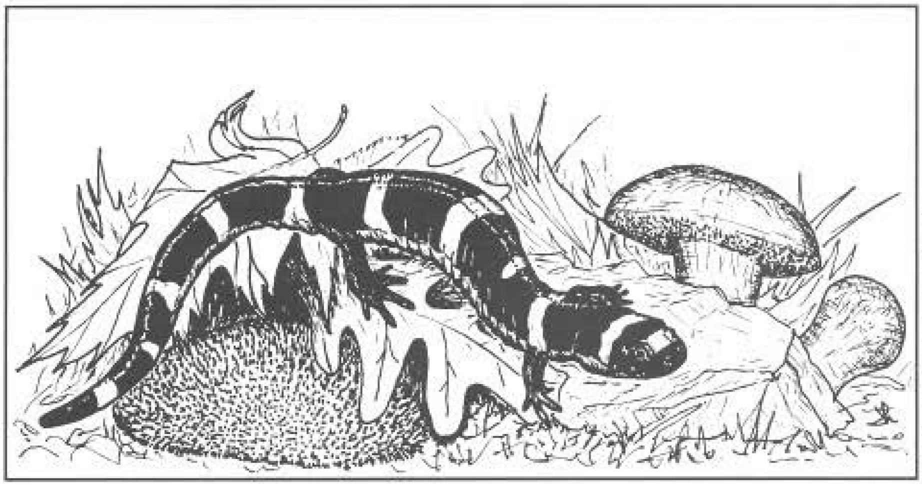
As is true of the mammals, a very accurate record of the changes in the distribution and abundance of Pleistocene mollusks and their environments can be pieced together from these widespread fossils. When other evidence is available from rarer sources, the sparse remains can often help corroborate the story told by mammals, clams, and snails. For instance, a few bones of frog or lizard, or the scattered shell plates of a turtle or tortoise from a cave deposit, or from the boggy soil around a sinkhole or spring can lend support to the overall picture.

Glacial Ice And The Ozark Endemics

While fundamental to the mix of terrestrial species, the coming and going of the ice sheets was even more influential in the distribution patterns of some aquatic organisms, such as plants, mollusks, some insects, fish, and amphibians. It's hard to live in water that has turned solid. Even while some aquatic organisms may possess the physical equipment necessary to disperse in front of an approaching glacier, or return behind a retreating sheet, such creatures are often tied closely to a particular set of physical conditions and may not be able to surmount environmental barriers easily. Some plants may need certain environmental conditions to blossom, while their seeds need another set to sprout. The eggs of an amphibian may not hatch in water too warm, too cold, or too murky. The same is true of fish. On the other hand, most insects, reptiles, birds, and mammals are capable of crossing nearly any barrier thrown in their paths by intervening ridges, grasslands, big rivers, or other hostile territories.

It is no coincidence that the principal Ozark endemic species, those that are confined to the region and found nowhere else, are mostly plants, fish, amphibians, and aquatic or semi-aquatic invertebrates. Even though restricted now, each Ozark endemic must have originated somewhere. It must have an ancestral home and an ancestral lineage from which it descended. By examining similar and closely related species elsewhere, it is often possible to pinpoint not only the origins of such endemics geographically and biologically, but often their origins in time as well.

The fact that these organisms are endemic indicates that they have not been able to exchange genetic material - that is mate - with any other closely related population. Had such genetic mixing or mating been possible, an endemic could not have developed into its own distinct type. Mixing of genes results in mixing of traits. This means the loss of the unique characteristics that make an endemic species distinct in the first place. Mixing of genes with an ancestral or closely related partner group creates a single, more-or-less uniform species distributed over an area that encompasses the ranges of both the endemic and the ancestral type. If truly endemic, two separate ranges of two separate and distinct species must be evident. In other words, the endemic plant or animal must be isolated.



The Ozark ringed or grotto salamanders have been confined to the Ozarks since the Tertiary uplift and have been evolving on their own for millions of years.

The high frequency of endemism among Ozark, Great Lakes, and Appalachian species tells a long tale of isolation, apparently with several phases. A few endemics are only distantly related to species in other areas, convincing evidence that evolution has altered the endemics over a very long period of time. The Ozark ringed and grotto salamanders are examples of such species. Confined to the Ozarks since the Tertiary uplift, and with no really close relatives nearby in any direction, these unique animals have clearly been evolving on their own for millions of years.

At the other extreme, a fair number of very closely related - even identical - insects, mollusks, fish, and amphibians shared by the Ozarks, Great Lakes, and Appalachians indicates that the isolation of such animals has been fairly recent. In some cases the related pairs not only look very much alike, they behave in very similar ways and still live in almost identical habitats. The process of change simply has not had enough time to produce striking differences between the two disjunct populations. To understand the role of the glaciers in producing Missouri endemics, and where the pairs of closely related species shared by the Ozarks and Appalachians came from, one must review the conditions and events of the previous geological period.

The Tertiary uplift of the Ozarks drained the ancient coastal plain, cut deep valleys, changed stream gradients, and opened caves. The environments of the Ozarks changed dramatically, thus isolating its newly evolved species. This initial phase of isolation produced by the Tertiary uplift did not last. While substantial, the barriers of slow-moving, warm, murky water and open terrain that surrounded the Ozark plateau after its rise 5 to 25 million years ago, were breached during the Pleistocene, but not by ice directly. Glacial ice never entered the Ozarks. Nevertheless, the advent of the glacial epoch greatly altered the environmental conditions in the Ozark highland, as it did in all of the surrounding areas. Along the ice front and into the Ozarks, summers were short and cool, while winters were long and cold.

Surprisingly perhaps, the exceptionally high summer and low winter temperatures that make headlines in Missouri today probably did not occur during a glacial.

Unlike the seasonal extremes experienced by midwesterners, the climate of the Ozarks during a glacial period, although significantly cooler, was also much more even-tempered. Missouri's worst highs and worst lows were not nearly so common then. As happens along our western mountain ranges today, cold winters were regularly interrupted by warm air masses, called **chinooks**, that descended from high ground. When air expands - as with the sudden and complete discharge of a pressurized aerosol can - it cools tremendously. Rising air also expands and therefore also cools. Conversely, as air is compressed, which occurs when air drops to lower elevations, it becomes heated. Sinking from the mountainous heights of an ice sheet or a mountain, such falling air masses create powerful and warming winds that actually raise lowland temperatures 30 to 50 degrees in an hour. On the other hand, Ice Age summers were cooled by the ice and were much wetter. The warm, moist air masses that surge up from the Gulf and create today's summer thunderstorms would have dumped their entire loads when they encountered the cold air along the edge of the sheet. The cool, but relatively uniform and mild conditions of the Pleistocene allowed northern species to live fairly close to the line of glaciers.

The aquatic species currently associated with the Great Lakes dominated Missouri waterways during an ice advance, just as the rest of the north's flora and fauna overwhelmed her terrestrial habitats. Each winter, when ice reclaimed the streams, the fish migrated deep into the southern states. As the flow resumed with each spring thaw, the fish returned. They came not only to breed, but also to feed. Plankton, midges, stoneflies, and caddis flies exploded with the spurt of algal growth spurred by the cold, mineral-rich meltwaters. Though such insects were extremely abundant in the creeks and rivers originating in the Ozarks, most could not survive in the choking, silt-laden flow from the glacial front itself. This inhospitable characteristic of glacial meltwater streams made our rain- and spring-fed Ozark streams even more popular. The Ozarks became a refuge for northern species of plants, insects, and fish.

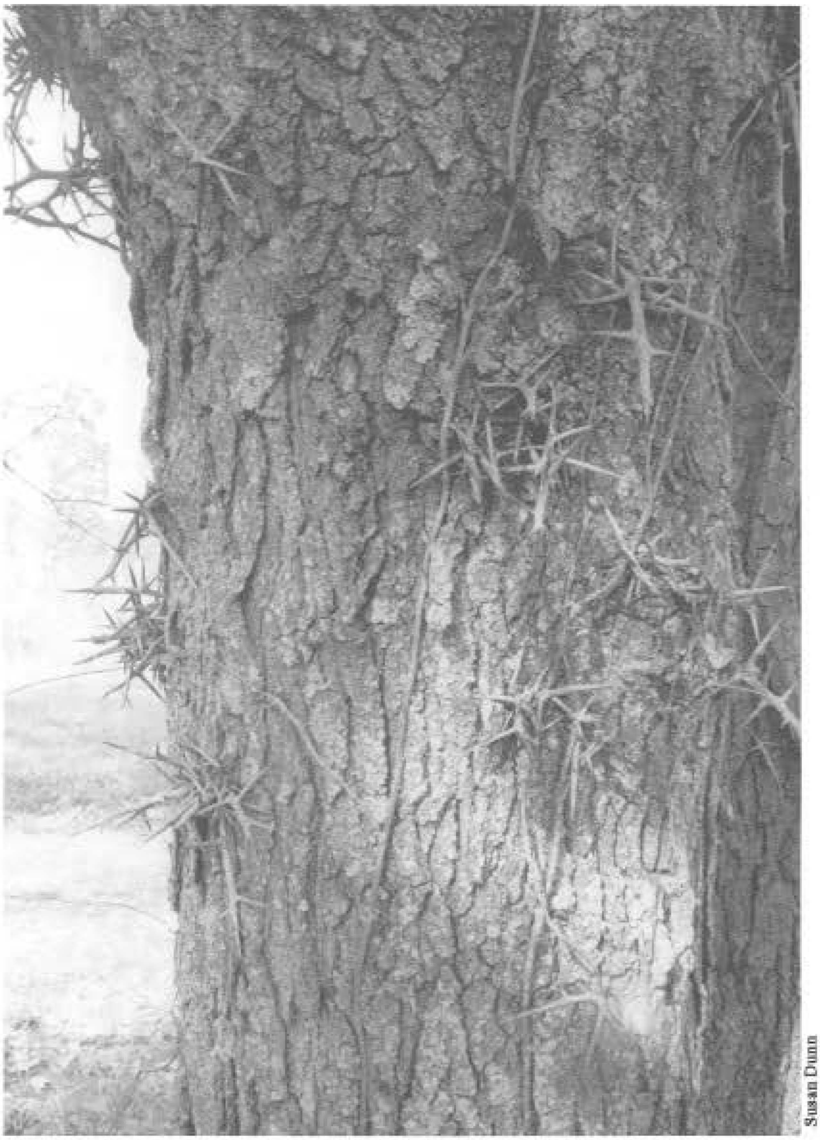
Each postglacial thaw flooded spring- and summertime waterways with icy water, establishing temporary links between the clear, cold waters of the upland Ozarks and similar streams in the Appalachians. Returning from their winter refuges in the south, migrating northern species had equal access to the cool, oxygen-rich streams draining into the Mississippi from both east and west. The simultaneous arrival of these species in the Appalachians and the Ozarks laid the foundation for the post-Tertiary phase of mixing and endemism. As the warm, silty big river barriers were reestablished between glaciations, such shared populations became disjunct and isolated.

Now isolated, the populations left behind in each highland were free to undergo independent adaptation to their own local conditions. Individual differences between the two upland environments could lead to subtle changes in shape, size, color, physiology, or behavior. Through this process, subtle differences which zoologists recognize as **races**; more important differences distinguished as **subspecies**; and finally, distinct **species** were established.

Some disjunct pairs of fish - such as the longnose darter of the Ozarks and the sharpnose darter of the Virginias, or the Missouri saddled darter and eastern variegated darter - were established early enough in the Pleistocene to now be labeled distinct species. The separation of others must have been more recent because they have changed only slightly in the short period of time available for evolution. The remaining disjunct populations have probably only been apart since the most recent Wisconsinan advance and are still clearly recognizable as one and the same species. The effects are seen not only in the fish and amphibians, but also among stoneflies, caddis flies, and other invertebrates. The cycles of migration, mixing, and isolation occurred four times, with each glacial advance and retreat.

Ozark links with the Great Lakes and the Appalachians were not the only sources of shuffled species. Connections also existed with drainages to the southwest and west of the Ozarks, including the Flint Hills of Kansas, the Ouachitas of Arkansas, and even the foothills of the southern Rocky Mountains in New Mexico. However, it is the north-south and east-west connections along the Mississippi Valley that are of primary interest at the moment. Studying the modern distribution patterns of fish and amphibians in this area reveals the great potential for isolation and mixing of species inherent in the advance and retreat of glacial ice. Again and again, glacial meltwaters seem to have given the fish and amphibians the means by which they could escape one region and enter another.

The list of species with northern affinities includes some of the numerous species that may have entered Missouri during the Pleistocene. Like the plants, some of these have been left behind in the south as rare or relict populations, cut off from the main group; others are



Susan Dunn

The honey locust tree reflects the separation of populations by the Mississippi River with close relatives in the Appalachians.

more common and widespread. Among those with disjunct populations are the northern brook lamprey; the blacknose, spotfin, and roseyface shiners; the channel, rainbow, and least darters; and the mottled sculpin. Once again, the list is not confined to fish. Some of the stoneflies and caddis flies that fed Ice Age fish survive in Ozark streams that simulate northern conditions. The four-toed salamander and the wood frog entered from the north with the last ice sheet, and probably earlier ones as well, and have left small relict populations behind. At least one reptile, the smooth green snake, left a similar trail of scattered populations in the south and west as it retreated north.

Some northern species became part of Missouri's fauna as a result of major shifts in river channels. For instance, the ancestral Missouri River originally flowed northeast to Hudson Bay, but was diverted southward into the Mississippi by the spreading ice sheet. The shifting river brought its fauna and flora with it when it came, including the pallid sturgeon, the sicklefin chub, and the sturgeon chub. Today, these fish are still confined to the Missouri River's muddy waters, but are now part of the state's biota as well, since the river itself changed course.

Many Ozark species have very close relatives in the Appalachians, cut off by the Mississippi River and its broad, inhospitable lowlands. Among these are the least brook lamprey; the Ozark, telescope, whitetail, and bluntface shiners; the slender madtom and northern studfish; the cavefish; and the gilt, bluestripe, Niangua, greenside, and banded darters. While the coal skink is the only reptile that displays this type of disjunct distribution, several amphibians have similar patterns, including the red-backed and long-tailed salamanders, and the hellbender. As expected, a large number of invertebrates match the fish and amphibians. Among trees, the shortleaf pine, scarlet oak, yellowwood, and black and honey locust reflect the separation of populations into eastern and western branches. Unlike the animals, each of these has continued as a single, intact species, reflecting the stable evolutionary history of such species, and perhaps the mixing of genes made possible by the easy dispersion of pollen.

The Pleistocene put the final touches on Missouri's biological as well as its physical landscape. The Ice Age introduced northern and eastern species into Missouri, while allowing some Ozark endemics to escape to the Appalachians. It left northern species behind as relicts in the Ozarks, Ozark species behind as relicts in the Glaciated Prairie. The advancing and retreating ice sheets almost completely reconstituted the flora and fauna of Missouri's waterways.

The Natural Landscape

The natural landscape of Missouri prior to the arrival of humans was the combined result of many geographical and geological influences:

1. Missouri's ecotonal position in North America;
2. The limits of Missouri's continental climate;
3. The mixing and separation of species allowed by the Mississippi, Ohio, and Missouri river corridors and barriers;
4. The mixing of South American, Eurasian, and North American species as a result of continental drift;
5. The ancient Ozarks as a center of evolution;
6. The diversity of rocks and resulting soils created by changing events over geological time;
7. The numerous habitats exposed by erosion after the Tertiary uplift;
8. The shuffling of Eurasian and North American species across Beringia;
9. The leveling of northern Missouri by glacial ice and the scouring of the Bootheel by glacial meltwater; and
10. The mixing and isolation of populations within North America as the glaciers came and went.

At least 10,000 years of human impact on the land and its creatures have often made the products of these many influences difficult to observe and comprehend.

The Ultimate Ice-Age Predator

Late in the Pleistocene, perhaps as early as 25,000 to 35,000 years ago or even tens of thousands of years earlier, but certainly by 10,000 to 12,000 years ago, humans also took advantage of the proximity of the northern continents. The difficulty in giving a precise date to the momentous occasion results from the inability of archaeologists to precisely date artifacts in absolute time, and their inability to come up with dates on which all can agree. Approximations for the timing of events that happened so long ago are about all that can be hoped for.

It is also quite likely that the human migration into North America was not a single event by a single group of people, but a series of invasions by different cultures extending over a period of many thousands of years. Travel by foot across Beringia is the most obvious means of arrival. Yet, even today Alaskan Eskimos sometimes paddle kayaks across the narrow Bering Strait, sometimes just to visit relatives in Soviet territory a few miles away. It is certainly possible that earlier cultures could have traveled such short distances in similar fashion. Crossing the short distance on sea ice is another distinct possibility. It is doubtful that anyone will ever be able to identify a specific group responsible for the first immigration into the New World, or even identify a single prehistoric period during which the first humans arrived. We do know it was NOT Columbus who discovered the New World.

Regardless of the means or time, the entrance of this alien, intelligent species, like the introduction of any foreign species into an established and balanced ecosystem, probably had very disturbing effects on the natural order. Humans in the late Pleistocene were well-organized, highly social animals with brains like our own. Simply put, they were people, just like us, but with a Stone-Age culture. Tool-making and weapon use, although not yet particularly advanced, were nonetheless a cut above the style and capabilities of prior generations. The mere fact that the animals of North America now faced a new type of predator would have been enough to put them at a considerable disadvantage. Adding the efficient hunting techniques of this new predator to the climatic and environmental turmoil already imposed by the passing of the glacial epoch must certainly have placed additional pressures on the Pleistocene megafauna.

Armed with the high-tech weapons of the day - fire, stone and log deadfalls and other kinds of traps, stone-tipped darts thrown with great force from notched sticks called **atlatls**, spears, and, most importantly, instantaneous and complex communication - these cooperative and well-organized bands of hunters were a predatory force to which North American animals had never before been exposed. Few defensive behaviors could have evolved to match these new assaults. After contact, the low reproductive rates, long generation times, and slow maturation rates of Ice Age mammals, like large mammals today, could not have allowed rapid genetic adaptation to the new threat. Of course, experience could teach some individuals how to successfully avoid this new source of danger, but as a group the naive great mammals were in deep, serious trouble. As the last ice sheet receded and the changing climate, habitat, and food sources took their toll, the additional presence of humans had an overwhelming impact on an already stressful situation. It should not be surprising, therefore, that the late Ice Age fossil record shows sudden and widespread extinctions across the entire continent.

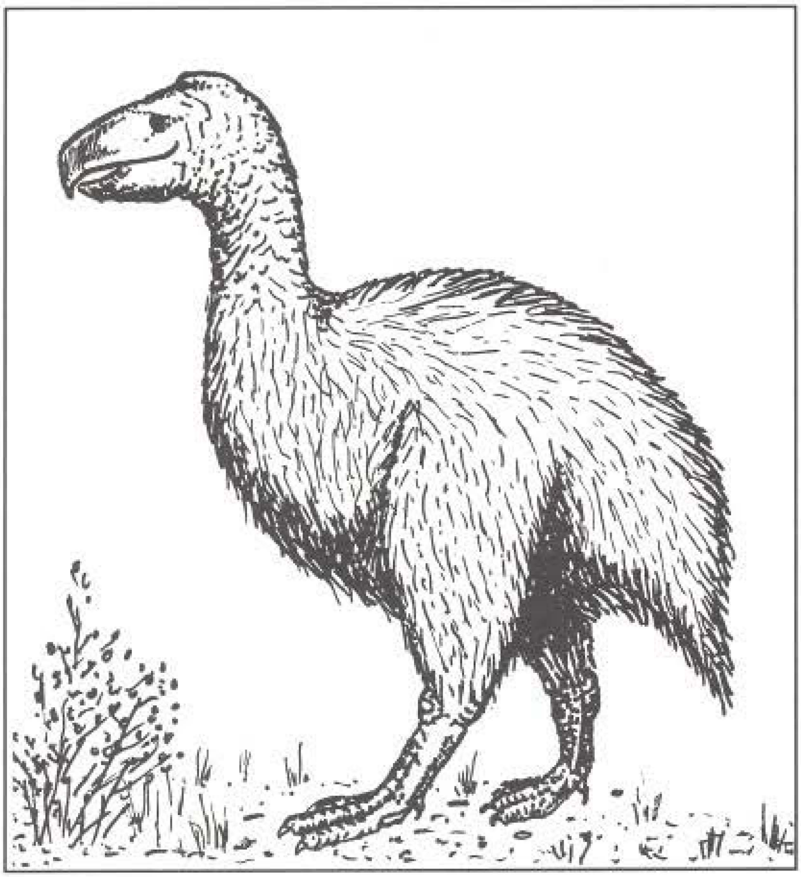
While some doubt that people could have been responsible for the demise of the mastodons and other Pleistocene megafauna, the arrival of humans and the mass extinctions of these great mammals appear far too coincidental for there not to be a connection. It seems unlikely that the change in climate by itself could have been totally responsible for the rapid die-off. After all, mammalian faunas had already endured, even thrived during three earlier glacial and interglacial periods. The extremely slow procession of glaciers in the past had evidently given animal populations a sufficient period of time to adapt and adjust to the changing climates. The only significant difference that occurred during the Wisconsinan post-glacial was the sudden presence of humans.

This extinction "event," if it can actually be referred to as an event at all, lasted for 3,000 to 4,000 years and has been referred to by some as the "Pleistocene Overkill." The disappearance of the large mammals in Eurasia about 100,000 years ago and in Australia between 5,000 and 30,000 years ago preceded the North American extinctions by many thousands of years. Each of these mass extinctions seems to be coincidental with the arrival of *Homo sapiens,* not with any particular change in climate or vegetation. South America was the last continent reached by humans and also harbored the last New World holdouts of the glacial age, many of which survived until as recently as 2,000 to 4,000 years ago. Interestingly, the survival of some Pleistocene-style mammals in Africa, such as elephant, rhinoceros, and giraffe, may be a reflection of two million years of coevolution with hunting humans, a coevolution that allowed adaptation to the behavior of the new predator. The familiar wildlife of the African savanna is, in fact, the Pleistocene megafauna, or what remains of it, now once again threatened by human technology.

The impact of humans is reflected among other groups of animals as well, and in times and places far removed from the glacial epoch of North America. For instance, the avian life of the late Tertiary had followed an evolutionary trend very much like the mammals. In fact, the Tertiary "Age of Mammals" could as easily be called the "Age of Birds." This parallel tendency toward extravagant numbers and kinds of birds also resulted, again as in mammals, in birds of very large size.

In the insular and mammal-free environment of New Zealand, for instance, over a dozen different species of flightless ostrich-like birds called **moas** developed. Some moas were turkey-sized, but a few stood 12 feet tall. An unrelated but similar group of giant running birds evolved under nearly identical circumstances on the island of Madagascar. These elephant birds, as they are known, though not as tall as the moas, weighed as much as 1,000 pounds and laid 2-gallon eggs weighing 16 to 18 pounds, the equivalent of 148 chicken eggs.

By the end of the Pleistocene, these megabirds, along with the megamammals, had all suffered a similar fate. Like our North American megafauna, the Madagascar elephant birds vanished after settlement in prehistoric times, but their empty eggshells were still used as water and mixing vessels well into European times. Some of the New Zealand moas are known to have survived into historic times, only to be driven into extinction by continued hunting on their once-remote islands. Moas were generally wiped out between 900 and 500 years ago by arriving Polynesian colonists, the Maori, who found them a delectable and easy food source, with the last disappearing at the hands of Europeans or Maori as recently as the 19th century. Hawaii suffered similar bird extinctions following Polynesian settlement. Similarly, the giant pigeons of the Mascarene Islands - the Dodo of Mauritius, and the Solitaires of Reunion and Rodriguez islands - were killed off as recently as 200 to 300 years ago by European sailors.



Diatryma was a 7-foot bird that lived in North America in the early Tertiary.

Even though the Gondwanan continents produced the world's greatest flightless birds, or **ratites** as they are called - the extinct moas and elephant birds, and the extant New Zealand kiwi, Australian emu, African ostrich, South American rhea, and Australian cassowary - North America once had some pretty big birds of its own. Long-legged species, like the 7-foot diatryma, had gone extinct here earlier in the Tertiary. Dry caves in Nevada have yielded the bones of the incredible teratorn, a vulture-like creature twice the size of a California condor, with a wingspan of 15 to 17 feet. Because of the great age of these fossils, it is highly unlikely that humans could have contributed to their demise. There is little doubt, however, about the role of humans in the disappearance of the North American mammalian megafauna, but absolutely no doubt about the human impact on the vegetation of North America. Into what kind of world did the first North American immigrants wander?

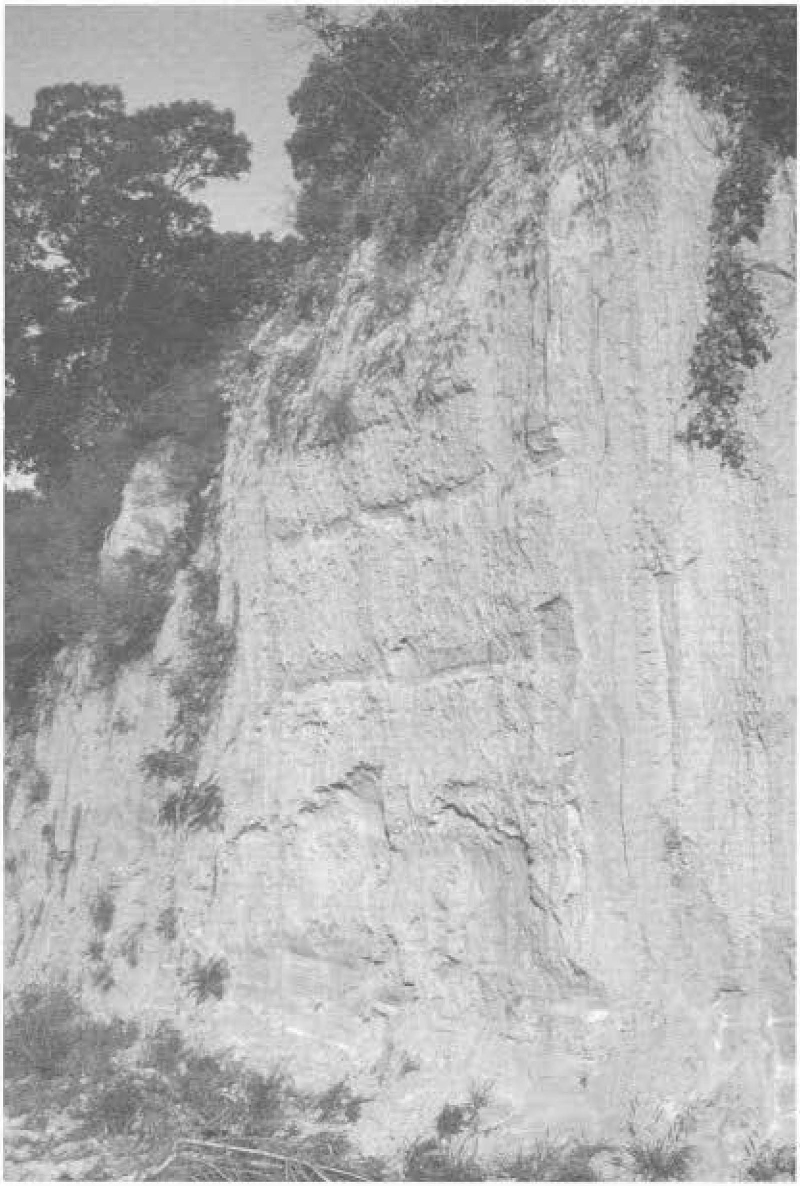
The Holocene - A Different Postglacial Environment

The withdrawal of the Wisconsinan Glacier occurred in stages over a period of many thousands of years, bringing to a close the age of the great continental glaciers, at least for a time. By the time of withdrawal, the terrain of northern Missouri had been ground flat by the Nebraskan and Kansan ice sheets, eroded deeply for over a million years, then buried beneath two heavy layers of glacial dust, or loess. Meltwaters had gouged river flood plains from Paleozoic rocks and flushed embayment muds from the Southeastern Lowlands of Missouri. Hundreds of kinds of animals had evolved and passed into oblivion. A number of new endemics had developed in the now isolated Ozarks, relict populations were left scattered about like a trail of bread crumbs, and populations of some species found themselves split between the Ozark and Appalachian highlands, or between the Ozarks and the Great Lakes. Eastern forest, western grassland, southwestern desert, and southern coastal species now prevailed. A number of factors conspired to bring about significant climatic changes: changing ocean current and jet stream patterns as the ice retreated; the tilt of the earth relative to the sun's rays; the distance from the sun to the earth; all combined to bring about a rapid succession of living conditions.

Early on, the evolving combinations would produce a dry Florida, a bitterly cold North Atlantic, a wet Southwest and East, and a mild Alaska. The cold, wintery Missouri climate at the height of the glacial shifted to a period of moderately warm and moist conditions. Then, after centuries of relatively high moisture levels, a warm, dry phase developed that lasted roughly 4,500 years. This was briefly interrupted by another moist period about 5,400 years ago. During the initial warming trend, sometimes called the "thermal maximum," western and southern species were able to expand their ranges farther east and north, and to slightly higher elevations than they are currently able to exist. Later, as the warming was repeated, and became steadily drier, these same western and southwestern species crept even farther east and north. Sagebrush, for instance, spread as far as central Minnesota, an area that has been dominated by forest for the past 3,800 years.

While these climatic changes occurred, the last straggling Pleistocene mammals disappeared. By this time, humans had been in the Midwest for several thousand years and the consequences of their presence were highly visible on the landscape. Although a natural occurrence, the incidence of fire increased significantly with the arrival of humans in North America. While many of the earliest human-caused fires might have been accidental, the

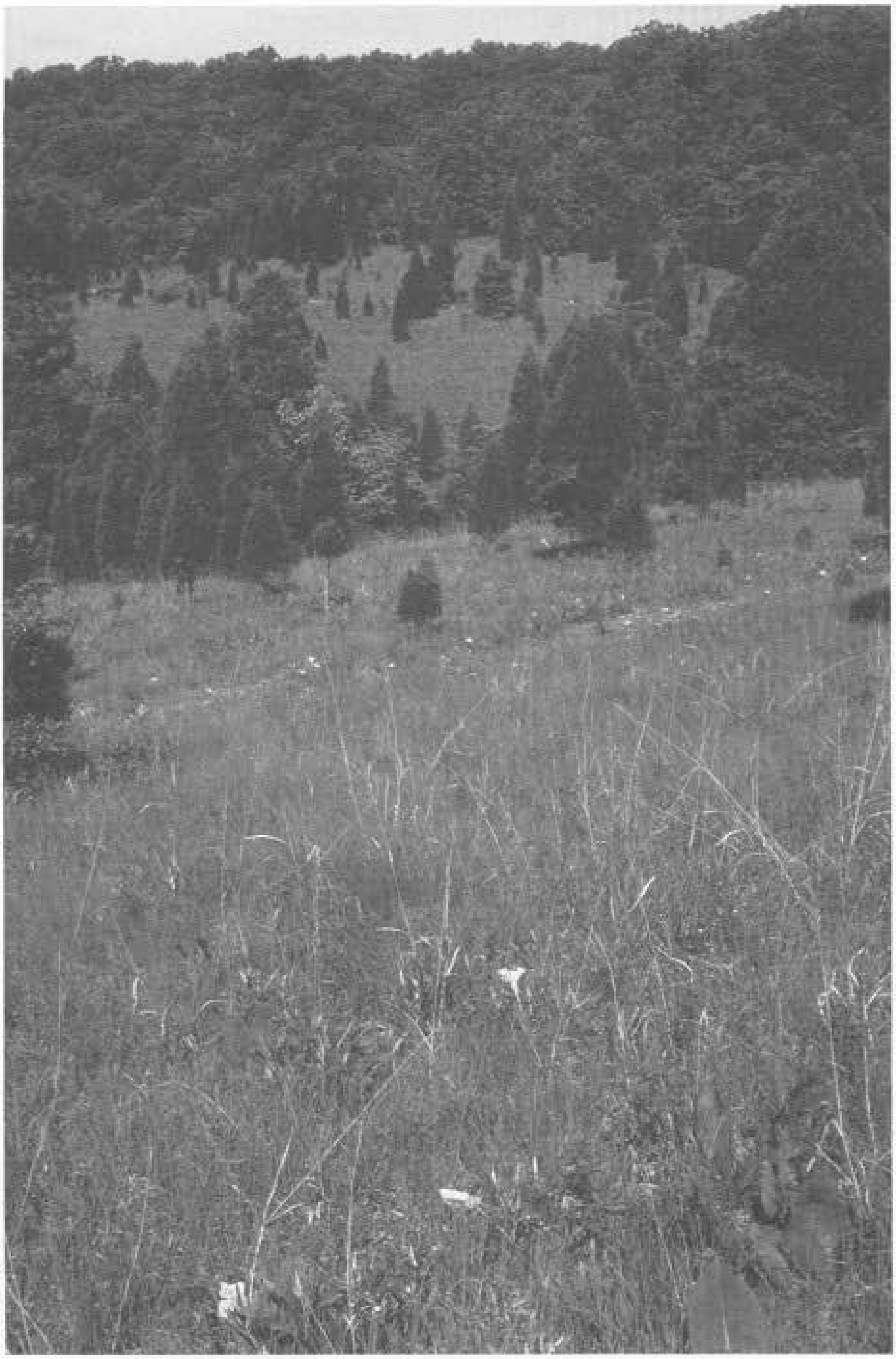
By the end of the Ice Ages, deep deposits of loess - wind-blown glacial dust - covered much of Missouri.



Jon Hawker

intentional use of fire undoubtedly increased with time as its beneficial effects became clear and people became more familiar with its control. As a hunting tool, burning was useful for driving game and creating second-growth habitats attractive to game. With the advent of agriculture, it became a valuable instrument for removing forest.

The desert-like environments known as glades expanded on Ozark hillsides as the post-glacial climate became warmer.



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In times of intertribal warfare or unrest, fire could become a fearful weapon as it spread unchecked across the land. It not only killed and destroyed villages and crops directly, it also drove away a rival's supply of game by ruining the forage in his territory. By the time Europeans arrived in North America, the tribes of the plains and forests had mastered the use of fire as both tool and weapon. Even as far east as Kentucky, where rainfall amounts are considerably higher than on the plains, the Shawnee kept several thousand square miles free of forest by regular burning. In the plains, millions of acres were burned every fall during massive buffalo drives when the animals were fattest and the prairie was driest. Similar fires are still a regular feature on Canadian Indian reservations.

In the first one or two millennia of the post-glacial, the eastward and northward spread of plains and desert species was almost certainly aided by human-set fires. Forests, already stressed by the drying climate, were even more vulnerable to the heat of periodic range fires. Savannas flourished as litter was removed and shrubbery and small trees were killed by spreading flames, then replaced by a lush layer of grasses and wildflowers. Prairies expanded into areas formerly held by forest as the trees were consumed by flames. A distinctly western set of communities moved into the newly-opened habitats of the Midwest and East. This expansion became especially apparent in northern Missouri and southern Iowa with the development of an ecological feature known as the **Prairie Peninsula**.

The Prairie Peninsula is a long, slender finger of grassland from the west that pokes the back of the Appalachians, while tickling the belly of the Great Lakes. Similar, but smaller strips of grassland, usually in the form of prairies or savannas, but often simply as the smallest forest openings called **glades**, extended along the ridges, south slopes, and flat plateaus of the Ozarks, again abetted by fire.

Jon Hawker

The testy badger is typical of grassland species that moved eastward along the Prairie Peninsula.

From Ice Age refuges or refugia well to the south and west, some as far away as Mexico, western animals followed the arid land plants taking advantage of the withdrawal of the boreal and deciduous forests. The spread of glade, savanna, and open grassland provided favorable habitats and access to the very heart of the continent. Lured by the plants of the Prairie Peninsula, western travelers moved into expanding eastern prairies, some reaching as far as Pennsylvania. Once there, a few of the western immigrants were able to expand their ranges, but for some the extension was too great. These failed to colonize the eastern prairies. Others may have drifted back more recently as a result of changing climatic conditions, or as a result of encroaching civilization. The list of western and southwestern immigrants is lengthy, but includes members of all animal groups, from invertebrates, fish, and amphibians, to reptiles, birds, and mammals.

Prehistorically, the northward and eastward spread of prairie and desert at the end of the Wisconsinan Glacier was the last major phase of natural floral and faunal development in Missouri. Historically, only minor changes in the distribution patterns of plants and animals, like armadillos and roadrunners for instance, can be linked to natural events. Since the end of the major post-glacial climatic shifts several thousands of years ago, virtually all changes in the populations and distributions of native species have been due to the impact of humans.

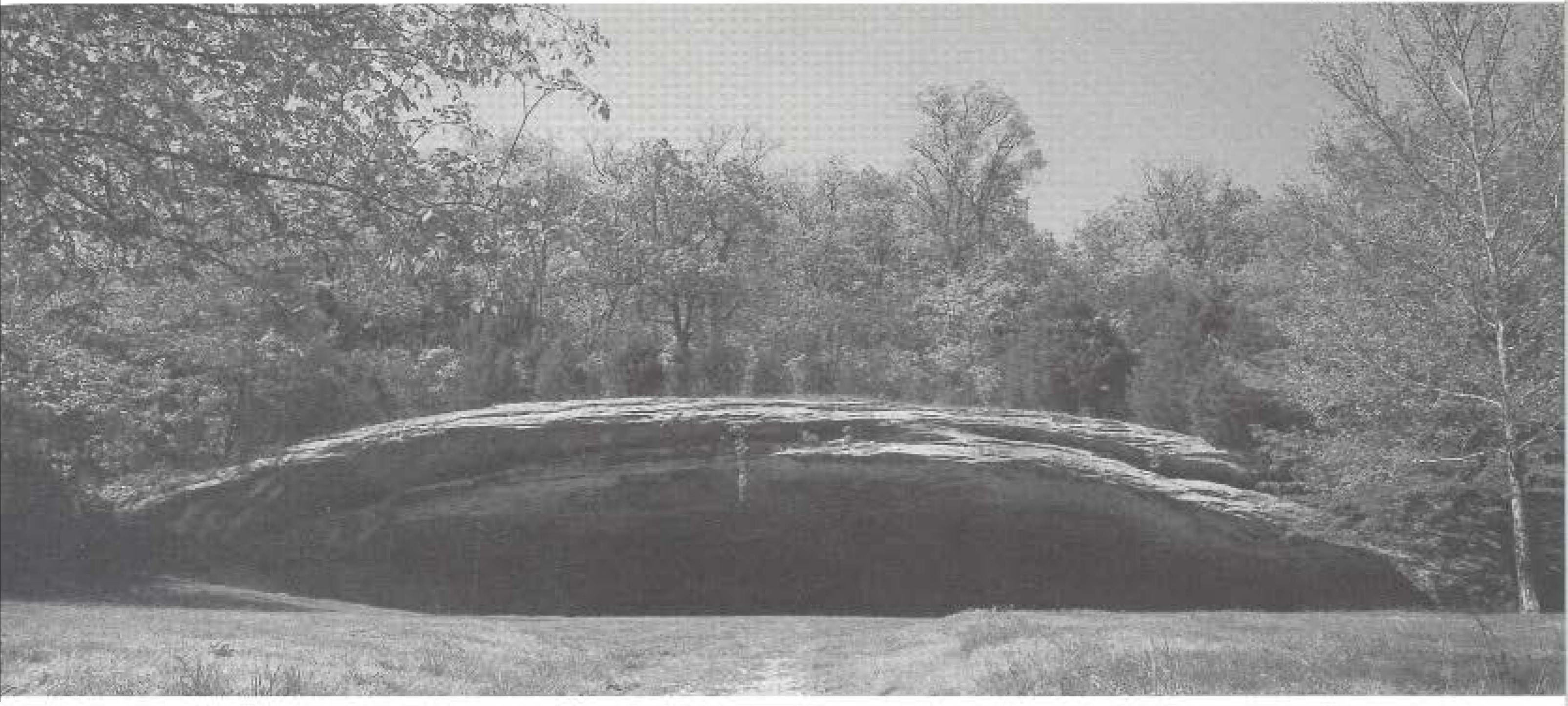
Pre-Indian Cultures

Following closely on the heels of the retreating glaciers, the first people to walk the land that would someday become Missouri were nomadic hunter-gatherers. Not yet considered Indians by ethnologists, these people are often referred to as **Paleo-Indians**. Roaming as small, tight-knit bands of both sexes and all ages, the basic unit of Paleo-Indian society was often the extended family, the type of society still seen in surviving stone-age cultures around the world today. Regions with more stable and predictable food sources were characterized by larger social units and greater permanence.

Armed with primitive weapons and fire, shielded from the cold and rain by skins, some of these people wandered over the land finding shelter under bluff faces and in cave openings. Some groups may have pulled brush into piles to shield themselves from wind or animals. Others migrated back and forth between one or two areas - perhaps a lush riverside location and a rich upland - moving only when local food supplies ran low. Aided by their older children and carrying their infants, the women provided the bulk of the family's vegetable dietary needs, including greens, seeds, fruits, nuts, roots, and mushrooms. This high-fiber diet was supplemented with protein demands in the form of eggs, insects, and such small mammals, birds, lizards and snakes, and fish or shellfish as they might be able to capture or collect. The men, aided by their adolescent sons, hunted and killed big game.

At first, while a variety of big Ice Age mammals was plentiful, such hunting was likely very successful and dietary needs could be easily met. After several thousand years, as the megafauna began to disappear, smaller game and food-gathering probably increased in importance. Populations of humans and their new prey, now consisting of deer, turkey, raccoon, opossum, squirrel, rabbit, and so on, were forced to strike a new balance. This transition from the far-ranging, nomadic life of a hunter to the more localized habits of a gatherer is generally recognized by labeling the 2,000 year interval of changing lifestyles the **Dalton Period**. It is possible that some groups never made any such transition, having relied on these food sources all along.

Jerry D. Vineyard



The centerpiece of Graham Cave State Park near Mineola is a large shelter cave in sandstone, that preserves records of human habitation as early as 8,000 years ago, in the aftermath of the last Ice Age.

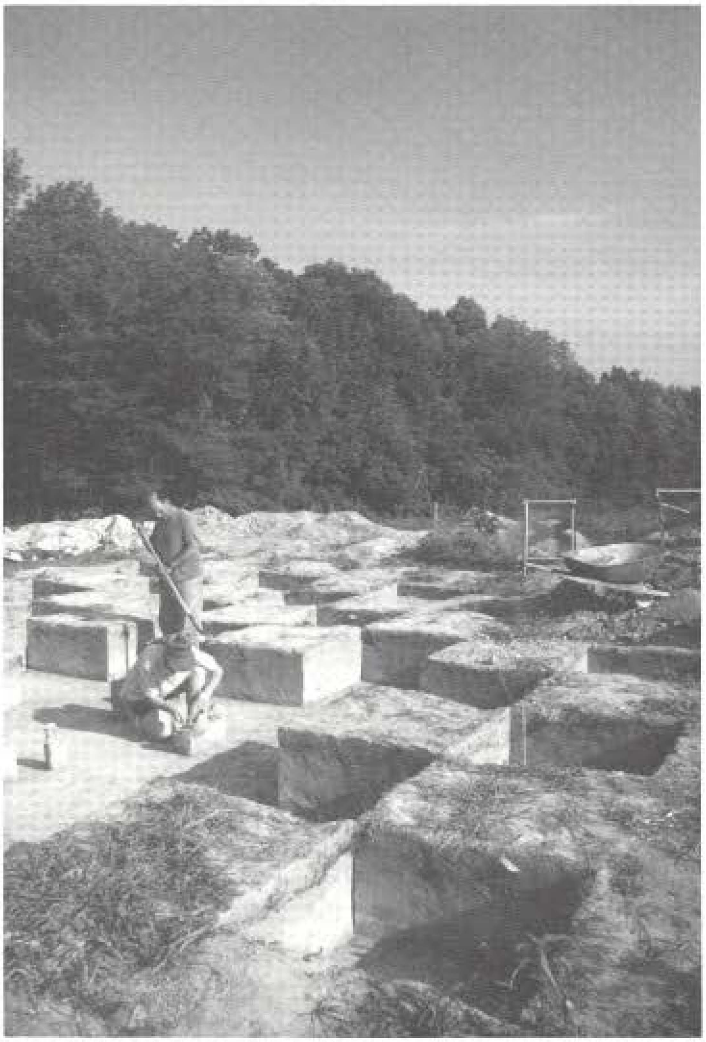
Although the major cooling effects of the glacial age probably ended in Missouri 8,000-10,000 years ago, meltwaters from the receding ice farther north continued to overflow the Missouri and Mississippi River flood plains and the Bootheel for thousands of years. Throughout this lingering period of thaw, the big rivers carried colossal amounts of cold, muddy water. Even historical floods have covered virtually all of our modern flood plains from bluff to bluff, and the entire Bootheel, from the Mississippi all the way to the Ozark escarpment. And modern floods simply can't compare to post-glacial summers that annually drowned every inch of the lowlands.

Clever folks that they were, the earliest bands of roving hunter-gatherers likely avoided the unproductive Big River bottomlands and the Bootheel during the early post-glacial. Little more than barren mud flats during the winter freeze, they raged with floodwaters each summer. It is far more likely that the Paleo-Indians took advantage of the bounty offered along Ozark streams, since these remained largely unaffected by glacial meltwaters. Certainly the river bluffs, Ozark hillsides, and prairie edges were hospitable, regardless of circumstances in the broad flood plains encircling the Ozarks.

On the other hand, considering the persistence and die-hard attitude of people who live along rivers today, it's not hard to imagine even these earliest Missouri inhabitants stubbornly returning to flood plains each time the water gave an inch. In any event, the oldest human artifacts in Missouri have been found in prairie and Ozark regions where life was more dependable at the end of the Ice Ages. Upland Ozark sites such as Graham Cave and Kimmswick extend human habitation in Missouri back 11,000 or 12,000 years.

The Rise Of The Indian

From digs such as this Dalton-age site in St. Charles County, archaeologists have pieced together much of the day-to-day lives of Missouri's earliest human residents.



Jon Hawker

In the Southeastern Lowlands the earliest human remains seem to date from what anthropologists call the **Early** or **Middle Archaic Period**, going back only about 5,000 years. Such a time frame would be consistent with the improvement of the environment as the ice became more remote, both in time and in space. In support of this sequence of events, the most primitive Archaic artifacts are found almost exclusively on the oldest and highest natural river levees and terraces, such as Sikeston Ridge.

Sifting through some of the oldest garbage in the state, archaeologists have uncovered fire pits and stone knives, choppers, scrapers, spearheads, and axes. More recent signs of habitation, such as delicate sewing needles, polished stone adze, and sophisticated scrapers, were all developed much later during the **Late Archaic**, about 3,000 to 1,000 years ago. These later sites are found in chronological succession on progressively younger soil surfaces, closer to the rivers' edges. This indicates that as the heaviest flooding dwindled, then ceased, Indians could take advantage of campgrounds or village sites that had been submerged much of the time earlier in the postglacial. Thousands of dark brown or blackish patches of soil dot modern farmlands where the organic remains of these old kitchen sites stain the ground. These old dumps, or middens, range in size from a few square yards to over 20 acres, and are commonly accompanied by potsherds and stone artifacts. Middens are obviously of great archaeological value and have been important in unraveling the story of early human life in the region. They indicate that as habitats changed in the Archaic, so did habits.

Period	Time	Tradition
Historic	A.D. 1673	Known Indian Tribes
Proto-Historic	A.D. 1450	Oneota and Village Farmer
Mississippi	A.D. 900	Village Farmer
Late Woodland	A.D. 400	Prairie Forest Potter
Middle Woodland	500 B.C.	Prairie Forest Potter
Early Woodland	1000 B.C.	Prairie Forest Potter
Late Archaic	3000 B.C.	Forager
Middle Archaic	5000 B.C.	Forager
Early Archaic	7000 B.C.	Forager
Dalton	8000 B.C.	Hunter-Forager
Paleo-Indian	12,000 B.C.	Early Hunter

Many Paleo-Indian bands moved frequently to maintain a supply of meat. From New Mexico to Florida and northward, excavations indicate close ties between these ancient hunters and herds of mammoth and mastodon. Following the large, slow-moving megafauna, the bands also migrated in response to changing quantities and sources of other foods, as well as water. Any direct impact these people had on the environment would likely have been limited to the effects of the burning they did to drive game, to campfires that escaped, and to the actual death of their prey. Of course, even these impacts could be intense (witness the demise of the game!). With the loss of mastodon, giant sloth, horse, camel, and giant bison, species of plants and animals still alive today came to play a larger dietary role.

Venison constituted a substantial portion of the meat intake of Dalton and Archaic cultures, but buffalo, elk, bear, raccoon, beaver, fox, bobcat, rabbits, squirrels, and various birds were part of the diet as well. Ozark streams provided mussels, crayfish, frogs, fish, and turtles. People of later periods relied more heavily on acorns and plant seeds as sources of starch and protein. An increasing number of stone-grinding tools among artifacts of the period testifies to this slow transition from animal to plant foodstuffs. Nomadic lifestyles gradually changed as the environment, and especially the flora and fauna, increasingly came to resemble that which the Europeans first encountered.

More than ever, people now tended to stay in one territory, circulating from upland to lowland sites with the changing of the seasons. Spring brought nesting birds to marshes and swamps. Summer droughts provided landlocked fish, turtles, crayfish, and mussels in accessible backwaters. The fruit and nut crop made uplands more attractive in the fall, and at the same time, rising testosterone levels distracted bucks and made them much easier targets. South-facing cave mouths and rock shelters warmed people through the worst months of winter, while similar hollows in north-facing bluffs made Missouri summers almost bearable.

As cultural levels advanced and as populations expanded, so also did local impact upon the environment. The intensified activity, confined to smaller and smaller areas, likely set up the conditions under which some common wild plant foods could have come under quasi-cultivation. Even a very rudimentary form of agriculture would guarantee a more stable food supply, diminishing the need for constant travel in search of food. The remains of small, seemingly more permanent base-camps in the Archaic Period attest to the establishment of an increasingly sedentary life-style.

Riverside campsites were probably in tougher shape than some of the worst we might visit in Missouri today. Trampled by hordes of playful little feet, cleared of trees by centuries of wood-gathering cooks, without a weekly collection of trash, the areas around the mouths of caves and along overhanging bluffs must have been quite a sight. The soil, heavily disturbed, open to the sun, and fertilized by centuries of human wastes, ashes, and garbage, would have been the perfect site for the germination of seeds spilled during collection, storage, and grinding. Crude baskets and sacks of woven grass were the only containers in use by the middle of the Archaic Period and these certainly dribbled their contents widely. Judging by the remains found in archaeological digs, the principal plant foods of the day were mostly weedy, riverbank annuals with prolific seed production, such as marsh elder, knotweed, canary and maygrasses, little barley, goosefoot, amaranth, and sunflower. All respond approvingly in such sunny, disturbed soils. Undoubtedly root and bulb crops were also gathered in large quantity, but such plant parts do not preserve well and even when they do survive, they are the devil to identify.

Returning to a site used in previous years, families would have discovered a ready-made supply of their favorite plant foods. It takes no great leap in logic nor any extraordinary brain-power to make the connection between the lush growth of plants on an old midden and the formalizing of the process. The next step is to clear and plant, followed by tending and protecting; maybe even, Lord help us, weed-pulling and watering. This likely sequence of events has been called the "dump heap theory" of the rise of agriculture.

Some genetic improvements were actually made in the cultivation of these plants as time went by. For instance, a large-seeded form of marsh elder no longer living today has been found in a number of archaeological sites. Such large, selected seeds would obviously provide more food than the smaller wild type. This kind of crop improvement can also begin quite accidentally. When picking wild products today, we all still grab the biggest, the juiciest, and the healthiest fruits, the heaviest clumps, and so on, obviously from plants with the best genetic traits for sweetness, productivity, disease and insect resistance, and so on. Scattered around a campsite, especially on midden heaps by night-visiting humans, the resistant seeds of such plants contain the genes that will be passed on to future generations in the dump-heap garden plot. Centuries of such selection practices will yield greatly improved varieties.

Modern corn farming, so much a part of the Missouri landscape, developed from Indian Maize. Here in test plots along the Missouri River near Hermann, varieties of hybrid corn are evaluated.

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Jerry D. Vineyard

Some of us older students may have learned in grade school or high school history courses many decades ago that the Tigris-Euphrates Valley was the Cradle of Civilization, the place where agriculture was invented. At the time, some of us may have wondered whether the folks in the New World simply sent for the free brochure from the Tigris-Euphrates Agricultural Cooperative, and if so, who delivered the mail. Throughout prehistory, plant domestication was accomplished by many different cultures, using many different plants, in many places on the earth, and at many different times. The Mississippi Valley was only one such place. People in the Mexican Highlands, for instance, developed their own native crops centuries before our eastern tribes. Of prime importance among these was **maize**, which we call corn.

Susan Dunn

Humans are the only animals who bury their dead. Cemeteries dot the Missouri landscape; graves are marked by engraved stones, sometimes of elaborate design.

With the domestication or even partial domestication of plants, more time would become available for other cultural advancements. By the Middle Archaic, for instance, people found time to put a fine finish on stone tools, and to produce purely ornamental objects of bone, shell, and stone. Clothing, including moccasins or sandals, was better tailored. Beginning in the Dalton, burials in demarcated cemeteries became a common practice, often accompanied by shamanistic rituals. This is a practice adopted by many cultures around the world that has continued into the present with an obvious impact on the landscape. Early European homesteaders and investigators came across many Indian graves, most more recent than the Dalton, and some more elaborately marked than others, and often rifled them for their buried treasures, trinkets, and souvenirs. With hightened sensitivity, many museums are now returning some collections of Indian remains and artifacts for reburial where direct lineage can be shown. Of course, pioneers brought their own burial practices to the new territory, marking individual or family graves with headstones, and fencing the plots to protect them from free-ranging cattle or accidental damage. In addition to the remains of the deceased and some historically tantalizing tombstones, some of these old pioneer cemeteries also harbor stands of original vegetation that have been destroyed elsewhere. Other old, abandoned cemeteries offer wildlife and vegetation an opportunity to reclaim land surrendered years earlier. With the growth of the state's population many thousands of acres of Missouri are now fenced, ornamented with carved stones of various kinds, meticulously cared for, and revered for the dead buried within.

In the Late Archaic and the early stages of the **Woodland Period** that followed, Missouri Indians displayed a tremendous variety of cultural styles. Deep in the Ozarks, pockets of foragers still relied heavily on game, while large populations of plant-gatherers occupied the grassland-forest border of the western Ozarks. However, the largest populations, very likely early agriculturists, were supported by the richer, better-watered soils of the central and eastern prairie borders, the expansive bottomlands of the Big Rivers and their tributaries, and the Southeastern Lowlands. The **Early Woodland Period**, from 1000 to 500 B.C., is another period of transition. The spread of primitive agriculture laid the groundwork for the acceptance of more refined techniques.

Between 1,500 and 3,000 years ago, domesticated Mexican species, including maize, beans, gourds, and squash, arrived via Gulf Coast trade routes established with the tribes of the Southwest. At about the same time, desert cultures also contributed techniques for the making of pottery. The advent of these items not only provided an abundant harvest, it meant that both food and water could be stored for long periods. The two advances released midwestern populations further from natural shortages than had simple dump-heap agriculture.

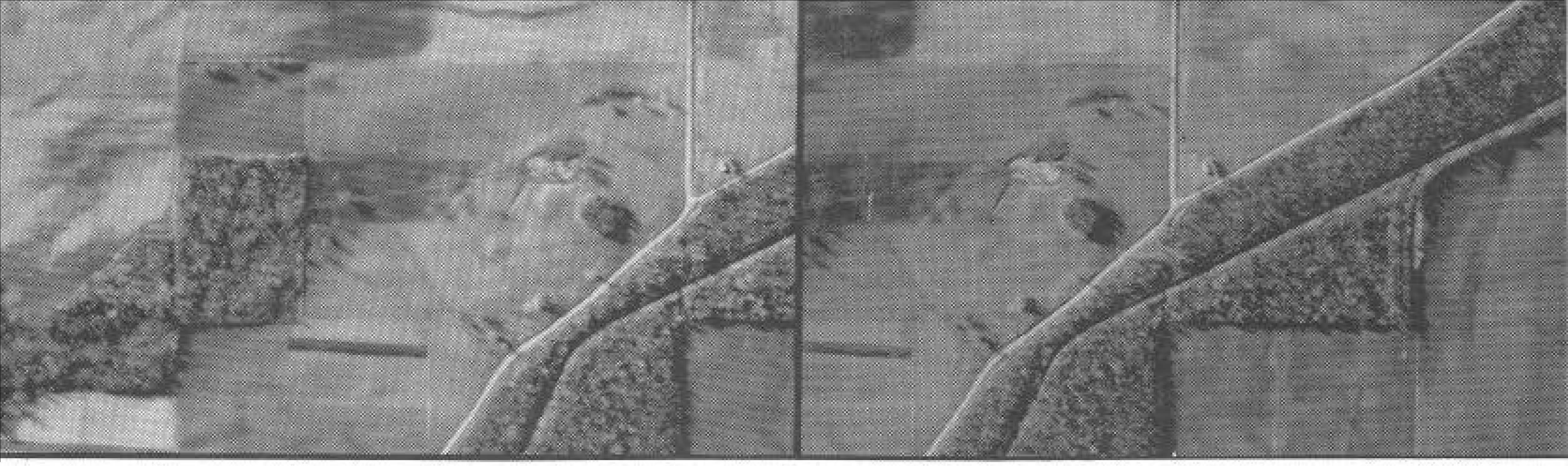
The influx of technology from the more advanced civilizations of the Mexican Highlands may be used as a starting point for the next phase in the cultural development of Missouri tribes, known as the **Middle Woodland Period**, about 500 B.C. The arrival of pottery and advances in the working of stone tools are clearly evident in the artifacts of the day. Even more important was the importation of maize about 400 A.D. The introduction of corn promised a steady supply of food and almost completely freed people from their older hunting and gathering habits. The growth of permanent villages became a common feature as a direct result.

Miller Cave, overlooking the floodplain of Big Piney River, offered shelter and security from attack to the bluffdwellers who utilized the site for many generations.

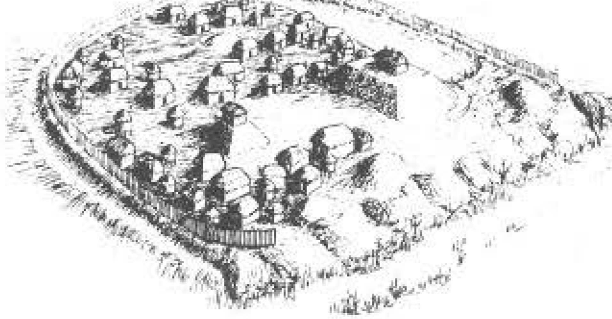
Jerry D. Vineyard

The Woodland Period lasted nearly 2,000 years and, with some cultural ups and downs, graded into the **Mississippian Period** about 900 A.D. Advancements in culture and technology swelled to a peak of magnificent proportions in this last pre-European stage. Together, the two periods saw the rise of intensive agriculture, burial and ceremonial mounds, ornate pottery, houses and towns, politics, complicated religious practices, astronomy, and transcontinental trade.

For the first time in the region's prehistory, people began to actually alter topography in order to provide themselves living space. For thousands of years natural structures, such as caves and overhanging bluffs, had provided Missouri's earliest humans sufficient shelter to survive rain, predators, winter cold, and summer heat. The primitive levels of technology used by the cultures that followed allowed the building of simple wooden structures covered with animal



Sterio pair aerial photos of Towosahgy State Historic Site in the Missouri Bootheel can best be viewed with a pocket stereoscope. The drawing below is a reconstruction of the site as it once may have been.



skins or leafy boughs wherever shelter was needed and natural refuges were not available. Such structures left no permanent marks on the landscape. Now however, as Mississippian people provided for their religious, political, nutritional, recreational, and domestic needs, they altered the physical landscape to an extent greater than any previous culture. Only the rise of 19th century European and American Technology, 500 to 1000 years later, had a greater impact on the land.

Defensive earthworks and wooden palisades ringed the larger urban areas of flood plains for protection against surprise raids by other tribes. Some of the largest earthen mounds in the world - the great temple mounds at Cahokia - were constructed during this period, and extensive fields were cleared for agriculture. Dugout canoes were used for trade up and down the river system. Copper was brought in from the Great Lakes, obsidian and mica from the Rockies and Desert Southwest, and conch shells from the Gulf of Mexico. Pottery was no longer of simple design and constructed solely for utilitarian purposes; instead, it became an art form in its own right, incorporating a great deal of ornamentation, often molded in the shape of animal or human figures and with intricately painted patterns. Elaborate religious and political ceremonies in city plazas indicate a strong centralized form of government dependent on a stable economy. Such organized, even regimented, systems became necessary to stabilize a society that had burgeoned well beyond a level that could be easily maintained by the older, extended family systems.

For 800 years, Mississippian agriculturalists expanded their culture and populations, converting thousands of acres of rich bottomland soil to staple plant foods. Dense, fortified urban centers, such as around Cahokia, Illinois, and Towosahgy, in the Cairo Lowland near Charleston, Missouri, grew to include as many as 30,000 to 40,000 individuals in fairly small areas. Today, the great mound systems and earthworks give some idea of the control these people exerted over their environment. The sheer number of Mississippian-age Indians undoubtedly pressured populations of animals to an extent greater than any other Indian cultural level before them. Even though these people maintained enormous agricultural holdings and stored large amounts of food for communal use, they continued to utilize wild foods to a great extent. Hunters stalked deer in the surrounding forests, drove bison far to the west, gathered acorns in the fall, and collected wild plants, fish, clams, and turtles along the rivers.

An Idyllic Indian Life?

Early humans and Indians have often been portrayed as living in complete harmony with nature, living off the land, taking only what they needed, and wasting little. This notion may be a trifle idealistic and may be based simply on the fact that most resources could not be exported from the area in which they were used. We should perhaps examine this idealistic notion a bit more critically.

Confronting a mastodon or a herd of buffalo on foot with a stone-tipped weapon would seem suicidal to most of us. It undoubtedly did to early humans and Indians as well. They weren't stupid. Heroics have no place in survival situations. A broken finger, arm, or leg; a punctured ribcage; even something so simple as a nasty cut could prove fatal with nothing more than Stone-Age emergency medical treatment. At the very least, such injuries would severely limit a person's ability to continue hunting and providing food; at the worst, infection might set in and death could result. Four-legged predators make some sort of judgement about which animals can be successfully attacked and killed, and which seem able to defend themselves. Reading cues that are largely hidden from our eyes, wolves leave 95 out of every 100 animals they approach unmolested. They somehow select vulnerable prey, mostly the very young, the very old, or the sick and injured. By using experience and judgment, large predators reduce the chance of injury.

Less selective by nature perhaps, certainly less well-equipped in terms of built-in food-getting devices like teeth and claws, primitive humans used what was provided them: hands and brains. These attributes allowed the development of tools, or what we call **technology**. From Paleo-Indian to Mississippian, a wide variety of tools were used to acquire food that could not be simply picked up with the fingers. Throughout the cultural stages we have described, early hunters used the easiest, most efficient methods of killing they could devise. If not the actual cause, the combination of hands, brain-power, and technology certainly accelerated the demise of many species.

Deadfall traps dropped logs and rocks on unsuspecting animals. Snares were used for small game. Whole herds were driven into corrals designed to capture as many animals as possible. This not only maximized the amount of food gained for each unit of effort expended, it also minimized the injury rate to members of the hunting band. Once corralled, animals could be swiftly and more safely dispatched. Fire was used on large-scale roundups to drive herds over cliffs, so that the dead and crippled could be easily butchered below. In an age without refrigeration, freezing, or canning, huge quantities of meat must have been wasted. Drying, smoking, and salting certainly worked, but to a limited extent. What about those really successful hunts? Five buffalo or ten deer might easily be butchered, stripped, and dried in a week, but how about 50 or 150? - or even one mastodon? Clearly, the idea of the shadow moving through the forest, taking only what was not needed, wasting nothing, and leaving only footprints is a trifle romantic. Romance doesn't last long in the wild.

Obviously, Indian use of fire as tool and weapon had widespread effects on both plant and animal distribution and abundance. In fact, the chief long-term environmental impact of native peoples all over the world results from their use of fire. True also, early hunter-gatherers contributed to the extinction of the Pleistocene megafauna. However, their harvesting of resources generally did not operate with grand scale economic motives. There was as yet no overseas market for Indian products and therefore trade was largely inter- and intra-tribal. Plant and animal products tended to stay in the neighborhood; such limited local demands could be easily satisfied.

Despite the cultural level they attained, the rise of agriculture, and the establishment of large cities, most Indians still lived largely at a subsistence economic level with regard to their biotic surroundings. Furthermore, their basically Stone-Age technologies simply did not allow the same degree of wholesale environmental manipulation and harvesting that the use of metals would have permitted. With the next wave of Eurasian immigration - this time mostly from the east, across the Atlantic Ocean, and not from the west, across Beringia - the situation would change drastically.

The arrival of predatory bands of humans in North America helped push the Pleistocene megafauna into extinction. Human-set fires, both intentional and unintentional, aided the eastward and northward spread of grassland and desert habitats during the warm postglacial period. This allowed prairie to exist much farther east and north than would have been possible simply as a result of climate. Indian burning also created extensive *areas of savanna throughout the timbered lands of Missouri. With the rise of native agriculture, dense populations of Native Americans developed and greatly altered the mix and appearance of local vegetation, especially along river valleys and the lowlands of the Bootheel. When compared to modern impacts, however, relatively low population and technology levels, coupled with lack of an outlet for natural resources, limited the environmental impact of the Indian.*

Initial Contacts - The Spanish

In their history courses, Americans are taught that the Italian, Cristoforo Columbo, underwritten by the Spanish, was the first European to visit the New World. In fact, five centuries before Columbus set foot on a Caribbean isle, Norse sailors came to the other end of the continent, to Newfoundland via Iceland and Greenland. Under the direction of Leif Ericson, they discovered a rich place they called "Vinland," the Land of Wine, because of the wild grapes growing there. There were migrating salmon, green grass in the middle of winter, and abundant trees, of immense value to Ericson's Greenland settlement which had no forests of its own. Vinland was probably the region around New Brunswick and the mouth of the St. Lawrence River, the northern limit of grapes and butternuts (found during archaeological digs at Viking sites and never found on Newfoundland) today.

Enticed by Leif's tales, other Norsemen ventured from Greenland to Vinland, using his camp as a base of exploration and exploitation, harvesting lumber, furs, and other articles that might bring a profit back in Europe. Clashes with the Indians and Dorset Eskimos, whom the Norse called Skraelings, soon broke out. Outnumbered, the Europeans eventually withdrew to Greenland. One of these exploratory groups stayed a few years at the tip of the great Northern Peninsula of Newfoundland, at a site known today as L'Anse aux Meadows. Here the Vikings constructed eight sod buildings, forged iron from bog deposits, and built and repaired their longboats. The brief presence of Scandinavians seems to have had little lasting effect on the New World, and certainly none as far inland or south as Missouri. We therefore begin our tale of dramatic change with the arrival of the Spanish.

When the first Spanish explorers arrived in southeastern North America in 1523, the people they encountered, and those met in the Mississippi Valley by the De Soto expedition in 1541, had large populations with well-established and highly advanced social, political, religious, and economic systems, strung together by a far-reaching communication and trading network that included most of the continent. Pottery and other forms of technology were advanced and agricultural holdings were large. One group of Indians calling themselves Casqui, living in large fortified villages with huts and temples on raised mounds of earth, provided De Soto with thousands of bearers and warriors to assist in his explorations of a neighboring territory held by a more powerful people known as the Pacaha, with whom the Casqui had been at war. These tribes may have been the last of the great Mississippian cultures in North America.

By 1673, the Indians encountered by the French along the Mississippi River no longer occupied the fortified town sites developed during the Mississippian Period. Most of the people seemed poor to the French, living in small villages dispersed over a wide area. Despite the initially positive impression Indians made on the Spanish explorers, in general the early French in mid-America saw little in Indian society to admire.

Some of the differences in Spanish and French descriptions may actually be due to differences in Spanish and French outlooks and aims. Desoto and other early Spanish explorers, the Conquistadors or Conquerors, were largely interested in the acquisition of material wealth and glory. Warriors all, they gained stature by overcoming resistance and subjugating, in other words by conquering. It would have served their heroic image to defeat a well-organized, intelligent enemy. The French generally came more quietly, to trade and deal, and to save primitive souls for Christianity. It would have served their purposes to convey an image of the Indians as a poor, ignorant group of savages in need of enlightenment.

Archaeological evidence shows that the Vikings beat Columbus to the "New World" by 500 years, thousands of years after humans first "discovered" North America.

Jon Hawker

In their overall philosophical views, both European groups were radically different from the Indians. Taught by the Bible to "subdue the earth and have dominion over every living thing," Europeans viewed nature as something to be overcome. Once subdued, the land could be "owned," a practice foreign to Indian cultures. Tribes held territory, but all members were the "owners" and benefited from the land; no individual owned any particular parcel. Beyond that, all things - hills, rivers, trees, animals - were endowed with spirits and were revered, a religious view known as **animism**. To harm the environment, to harvest more than could be naturally replaced were acts that, in most instances, were alien to Indian cultures. Animism was just dying away among the peasantry of Europe after centuries of Christian influence.

Most Europeans could not philosophically view a complex Indian political system or an obviously well-administered Indian town as products of a people they came to conquer, products of a civilized society. Thinking of the Indian as mere savage made exploitation easier. Yet, at least some of their lack of respect was likely due to the grave degradation of Indian society that occurred between the times of Spanish contact and French exploration.

There was, in fact, much less to admire. Following De Soto's expedition, European diseases decimated previously unexposed North American populations, often killing half, three-fourths, or more of the people in every village. Whole families were wiped out and the kinship hierarchy of chiefs and chiefdoms, indeed every phase of life, was severely disrupted. The diseases - smallpox chief among them - took politicians, priests, warriors, hunters, care-givers, and artisans without regard to rank or importance. With the losses of so many vital links it is not surprising that the very fabric of Mississippian society disintegrated.

It is also not surprising that later Europeans and Americans concluded that the builders of the great mounds and earthworks, and the potters and artisans who left so many beautiful artifacts must be of another greater, and (obviously) long-vanished race. Even early archaeologists seemed baffled by the mysterious disappearance of so great a culture. Today, we recognize that the historic Indians of the Midwest and South encountered by the French were the direct descendants of the Moundbuilders, and that the people met by De Soto and other early Spaniards WERE the Moundbuilders. Was European disease the only factor in the disappearance of the people that actually built the mounds?

A number of theories have been offered over the years to explain the decline of the Mississippian culture, one of the world's most advanced stone age systems. In addition to plagues, wars, drought, and indolence have all been proposed. Perhaps all could have played a role at one time or another, to one degree or another. Evidence is mounting that, between 1275 and 1350 A.D., a number of stressful situations began intertwining that could have proved the Moundbuilders' undoing.

We know that in the Desert Southwest, severe droughts at the end of the 13th and the beginning of the 14th centuries brought the collapse of the great Pueblo cultures. Certainly such widespread climatic changes must have been felt in the Midwest as well. On the other hand, cultures in the Ozarks that were far less advanced survived intact, and eventually took over territories originally controlled by the Mississippian tribes. What was it that favored hunter-gatherers over city-dwelling agriculturists?

When the Indians adopted an agricultural system based on corn, they may have unknowingly been sowing the seeds of their own downfall.

Susan Dunn

When the Indians adopted an agricultural system based on corn, they may have unknowingly been sowing the seeds of their own downfall. As long as they lived in hunter-gatherer societies, humans maintained a tremendously diverse wild diet, without over-reliance on any one particular food source. Populations also remained small, a consequence of a natural balance struck with food availability. As maize, squash, and beans replaced wild foods, the overall nutritional value of the diet declined, while heightened productivity increased populations dramatically. Outwardly, Mississippian society appeared strong, and its culture and technology both advanced, products of greater amounts of free time. Unfortunately, the general health and vitality of the people might have been going steadily downhill.

Most of us would suppose that a guaranteed steady diet, freedom from want, a decline in injuries incurred while hunting, and a prosperous society in general might improve health and increase longevity. In fact, just the opposite may have been happening in some Mississippian villages. In the Late Mississippian, the inhabitants of some villages seem to have suffered more from diseases, more often, and died younger than the Woodland cultures who preceded them. In general, the great Moundbuilders were smaller in size, had poorer teeth (unlike potatoes, corn and other starchy grains are great rotters of teeth!), and weaker bones. Arthritis was a common affliction because of long hours spent hunched over tilling fields.

Instead of security and stability, large population size led to increased strife between tribes, families, and individuals. Natural resources, such as metals and salt, were needed in greater quantities as wealth and populations increased. As resources became more valuable, they became worth fighting for. Territorial claims had to be defended. The rise in warfare yielded a painful harvest of injuries and infection.

Drought, warfare, a fracturing of the political structure, disease, all tore at the fragment of Mississippian society for 50 years or more. In the end, the system succumbed. Families fled to the hills where they could gather food, or to the east and south where other population centers still flourished. As the large village centers of Cahokia, the American Bottom, and the Cairo Lowland crumbled, new liaisons were formed and new tribes were created. And it may all have been from eating too many Fritos!

Generations later, the Indians who survived to confront the Spanish were still a well-disciplined and resourceful people, carrying on many of the traditions of their ancestors. However, there seems to have been a degree of reversion to the older methods of food gathering. While lowland areas were densely populated wherever the well-drained sandy soil of old river terraces was capable of supporting cultivation, native villages seldom attained populations of over a thousand individuals. The Spanish noted in their journals that, besides rich harvests of corn and vegetables, abundant game and fish were supplemented with an assortment of wild fruits, seeds, and nuts. In some late Mississippian digs, archaeologists have actually noted a higher diversity of wild foods than is usually found in much older hunter-gatherer sites. With the varied diet they were probably healthier than their forebears.

Though naturally hospitable to strangers, these Indians quickly guessed that Spanish intentions were not of the highest order. Because news of their arrival and harsh practices spread quickly before them, the Conquistadors were forced to overcome strong resistance wherever they went. Armed only with stone weapons, the native peoples generally incurred heavy losses in these battles. Even without bloodshed, the populations suffered terribly whenever contact was made from European viruses and bacteria. Even without contact, virulent diseases like smallpox rampaged through the intertribal trading and communication network. The microbes spread throughout the trading network within 25 years, wreaking havoc even in isolated areas.

The exchange was not, of course, entirely one-way. In a subtle example of tit-for-tatism, beginning with Columbus' crew, the Indians sent many Europeans back home with their own personal souvenir of the New World - syphilis. The disease reached plague proportions across the continent within 50 years. Even more far-reaching, the first shipment of Virginia tobacco was sent off to England in 1617. By 1638, more than 3 million pounds of the dried leaves were shipped to England. While smallpox has generally ceased its depredations, and syphilis has largely been brought under control, the Indian's tobacco has now become the world's leading cause of preventable death.

Other Indian gifts to Europe were not so clearly negative. One mixed blessing, the potato of the Andes Indians, quickly became the standard fare of working classes throughout Europe, leading to a general improvement in health and fecundity. Unfortunately for the Indian, the high populations also led to revolutions in many countries. The refugees and exiles naturally overflowed into America. On a clearly positive note, we have the Indian to thank for modern spaghetti and pizza, because no Italian dish ever had tomato sauce until the plant was brought back from the New World.

Jon Hawker

Travelers in northwestern Missouri may be surprised to stumble across fields of tobacco and drying sheds.

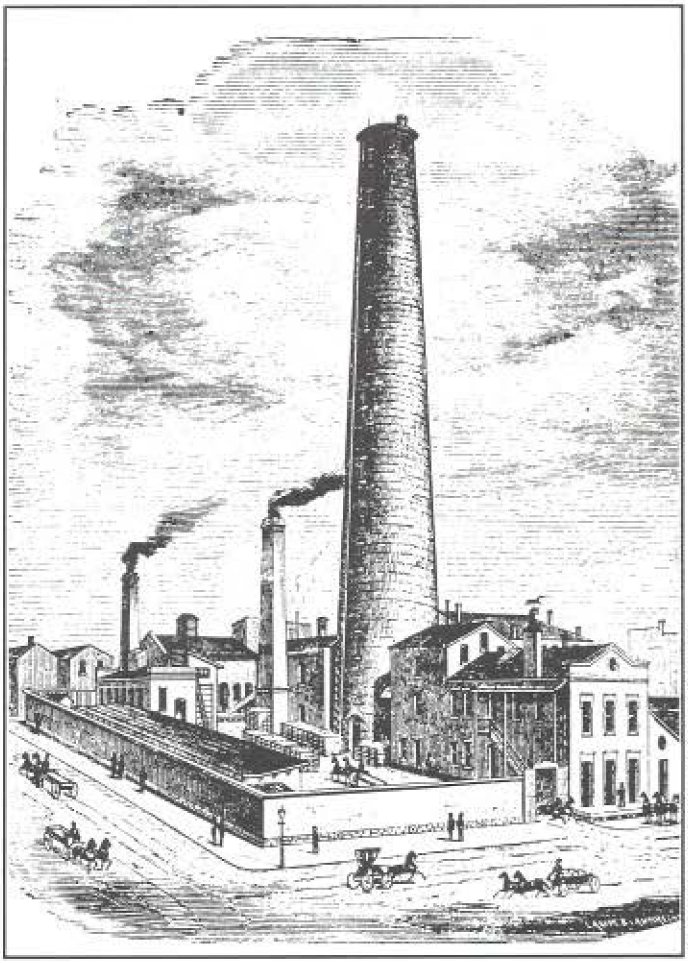
Many people have wondered whether Hernando De Soto ever reached Missouri, as some have claimed. We do know that he and a well-armed band of about 500 men ascended the Mississippi Valley in 1541 in search of silver and gold. Traveling along the strip of high ground on the west side of the Mississippi River called Crowley's Ridge, De Soto probably marched as far as Mississippi County in northeastern Arkansas. Some have suggested that he actually entered the Missouri Bootheel, but this is doubtful. However, two of his men may have searched for gold in the St. Francois Mountains of western Ste. Genevieve County in the company of traders. They returned to De Soto's camp after 11 days with a load of copper and six loads of salt, but no encouraging reports of great wealth. After resting for about six weeks with the Casqui Indians, De Soto became restless and returned a short distance south before heading westward into the Arkansas highlands, still in search of fabled mineral deposits.

In European Hands - The Coming Of The French

The first Europeans definitely known to have seen Missouri territory were a group of seven French led by Louis Joliet and Father Jacques Marquette. With hopes that the Mississippi would provide a passageway either to the colonies on the Atlantic, or to the Pacific, the small party had traveled in two birchbark canoes hundreds of miles south from the French Canadian territories in 1673. In July, having passed the mouths of both the Missouri and Ohio rivers, they finally reached an area in southern Arkansas. Because they were still traveling south, the two leaders correctly surmised that the great river flowed neither to Virginia, nor to the Pacific, as they had hoped. The Mississippi was obviously carrying them straight into the arms of the Spanish, who controlled the entire Gulf Coast. Worried that they might shortly intercept hostile Spaniards, the group began the six-week return trip on July 17. It was not until nine years later that Rene' Robert Cavalier, Sieur de La Salle, completed the downstream journey to the Gulf. Not encountering any Spanish on the entire trip, La Salle claimed all he had seen in the name of Louis XIV, established a settlement in Texas at Matagorda Bay, and named the new territory Louisiana.

In 1700, another Jesuit priest, Father Gabriel Marest, ventured down the Mississippi and established a village for displaced Kaskaskia Indians at the mouth of the River des Peres, whose headwaters originate in St. Louis' Forest Park. The Kaskaskia, a small tribe of Illinois Indians, had been forced from their lands on the east bank by the pressure of encroaching eastern tribes. In an earlier application of the domino theory, the tribes invading Kaskaskia territory had been driven from their own lands by the expansion of English colonies along the Atlantic coast. The site chosen by Father Marest now lies within the present city limits of St. Louis. Though his settlement was soon abandoned, a new town of Carondelet would be re-established at the same place under Spanish rule many years later.

Fifteen years later, the French Governor of Louisiana, Antoine de La Mothe Cadillac, traveled with another small party from his headquarters in New Orleans to the mouth of Saline Creek, just downstream from the future site of Ste. Genevieve. His goal was to track down a lode of silver rumored to be somewhere in the area. From the river, Cadillac pushed inland to the vicinity of Madison County in search of the elusive deposits. Instead of silver, he found only silvery lead, an event that would prove to be far more important to the future state of Missouri. The site of his discovery, which would wind up being mis-spelled Mine La Motte, set the stage for a program of mineral exploitation that only a century later would place the state in the forefront of world mineral production. Another hundred years after that, continued exploitation would culminate in disputes between mining interests and conservationists.



The State Historical Society of Missouri, Columbia

Lead shot tower in St. Louis. Drops of molten lead falling through the inside of the tower formed spheres of lead shot.

As a base from which to open the region to development, the French established Fort Chartres on the Illinois side of the Mississippi a short distance upstream from Saline Creek, completing its development in 1720. Sometime between 1723 and 1725, a French entrepreneur, Phillipe François Renault, received a grant to operate lead mines in the Washington County area and was shortly thereafter recovering as much as three-quarter ton of lead each day. Crudely molded into the shape of a horse's collar, then hauled to the Mississippi on the necks of mules, the metal was shipped downstream from a site that, around 1735, would become the port and trading center of Ste. Genevieve. By then, with the help of 500 slaves, Renault was extracting lead from at least three sites: Mine La Motte, Mine a Breton, and Fourche a Renault.

Although Ste. Genevieve was the first permanent European settlement on the west bank, Europeans had actually been living in the region, scattered about in small numbers, for 30 years. The Osage Indians were trading large quantities of beaver pelts with the French at a site called Fort Orleans, located on the Missouri somewhere in Saline or Carroll Counties, above the mouth of the Grand River. Established in 1724, the fort was abandoned two years later. By 1744, there were about 1,000 immigrants living in Missouri, of whom roughly half were French. In the meantime, French settlements mushroomed up and down the broad Mississippi flood plain on the Illinois side of the river, including St. Phillippe in 1723 and Prairie du Rocher in 1733.

The Indians quickly recognized the usefulness of the many modern goods that the whites brought with them and happily adopted those that suited their needs or fancy. Iron and brass implements, textiles, crockery, and glass quickly replaced stone, antler, bone, pottery, and skins. To obtain these prized articles, a lively trade in Missouri furs, salt, and lead had been established by 1705. The practice immediately changed the motive of Indian hunting from a subsistence economy that was mainly food-oriented, to a barter economy based on material gain. The change would quickly result in a population decline among principal game species. Even worse, this early decline would soon be accelerated by a heightened demand for meat because of immigration of Indian populations from the East in the late 1700's, followed by an explosion of white immigrants after 1800. In 1780, Missouri was already inhabited by about 5,000 Osage Indians and 1,000 Missouri Indians, plus an unknown number of Illinois, Quapaw, and Chickasaw. And those numbers would soon swell.

Who Shall Control The Wealth?

For nearly a century, and in various combinations, the British, French, and Spanish quarreled, finagled, and warred to decide who would control North America. In 1756, the English threw all they had into the fray, escalating an American offshoot of the Seven Years' War called the French and Indian Wars. With control of the seas and a powerful Indian ally, the entire Iroquois Nation, at its side, Britain eventually destroyed the French empire in Canada. To cover her massive war debts, the French crown, never really enthusiastic about its American holdings anyway, willingly agreed to cede all of Louisiana to Spain in 1762. With the signing of the Treaty of Paris in 1763, France relinquished the rest of her New World interests, namely Canada, to the British.

In those days, however, the hand-delivered news traveled slower than tax refunds today. In 1764, two French colonials who had not yet received the message, Pierre Laclede and his 13-year-old clerk, Auguste Chouteau, were already well on their way to founding the new city of St. Louis, a full year after the shift in Louisiana's fortunes. By that time, 40 or 50 families had already crossed from the Illinois side of the river and had established a thriving village. Crossing the river, they assumed they would still be under French authority and would escape the British threat. Instead all found themselves under the rule of the Spanish, the first landlords of St. Louis. A slow starter, St. Louis would not surpass Ste. Genevieve as a fur center until after 1800.

Spain, having suddenly inherited the vast Louisiana territories, set about strengthening her position. The Spanish were especially concerned with the aims of the British, who were not only vitally interested in gaining control over the entire Mississippi valley as a trade route, but from their newly acquired Canadian outposts, were now in a position to do something about it. When Spain took over the region there were still only two settlements on the west bank. Ste. Genevieve was thriving in the south with about 600 residents, including a fair number of slaves. To the north was the somewhat smaller St. Louis. This was immediately recognized as neither a particularly secure nor a strategic position to be in.

To gain the immediate and decisive increase in defensive manpower needed to hold off the British, Spain contrived to attract Americans to the west bank. With promises of land and the guarantee of religious and certain other freedoms, many Americans would soon push west. Folks in Kentucky were especially interested in such offers. Up and down the Appalachians and in the Piedmont of the Carolinas, residents had become steadily disillusioned with the slow progress of the struggling union, what they perceived as disinterest in the needs of interior farmers, and displeasure with a growing trend toward a strong central government in Washington. As the pro-centralization forces, the Federalists, gained strength at the Constitutional Convention in Philadelphia in 1787, the Kentucky region became a hotbed of Anti-Federalist intrigue and potential mutiny. Initially the Spanish had hopes of inciting Kentucky into actually seceding from the foundering United States, but chose the time-proven path of bribery and subversion instead.

One of the first to rise to the bait was the disgruntled George Morgan, of Princeton, New Jersey, a part-time revolutionary war hero and full-time wheeler-dealer. Ever the salesman, Morgan managed to negotiate a very favorable bargain with a representative of the Spanish, Don Diego de Gardoqui, who just happened to be in Philadelphia trying to patch things up with John Jay, the American Foreign

Secretary. The fledgling United States government, then known as the Central Government of the Articles of Confederation, was not yet our modern federal government. The Constitution would not be ratified for a year, so the United States government as we know it today did not yet exist.

Morgan was restless with the situation in Kentucky. In part, he was frustrated because the Central Government was in no position to offer protection to its citizenry on the frontier. Mostly, however, Morgan was just angry because the federal government had refused to support another of his get-rich-quick land schemes. Since the Spanish were prepared to offer Morgan and any other interested parties the somewhat illusory protection of the crown, bolstered considerably by the forces of the immigrating Americans themselves, and large tracts of land, Morgan was easily persuaded.

Mainly attracted by the offer of sizeable chunks of free land, the scheming Morgan left Fort Pitt with a large body of men in January 1789, floating down the Ohio to the Mississippi. Some 70 miles or so downstream from the broad confluence of the two rivers, on the high outside bank of a large meander loop, he selected what to him appeared to be a perfect spot for the capitol city of his new empire. Always a manipulator, the back-slapping Morgan, not too subtly, named the town New Madrid. Although under the watchful and somewhat suspicious eyes of the Spanish, Morgan's town became the first American settlement west of the Mississippi.

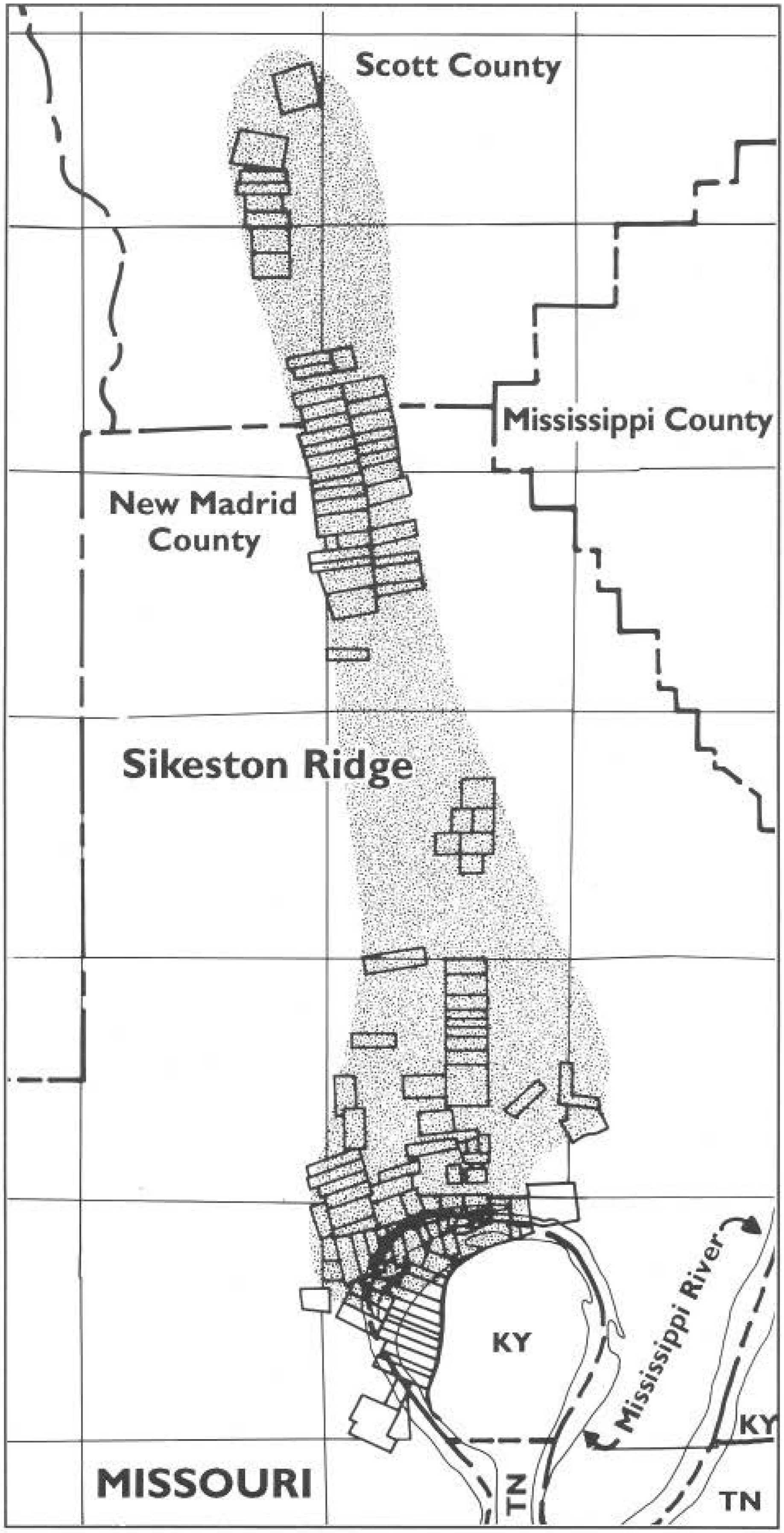
Despite Morgan's obvious leadership capabilities in other areas, the site would prove him a poor judge of geography and nature. His chosen bend in the river had for years been the site of a French trading post generally referred to as "L'Anse à la Graisse," or "the cove of grease." The origin of the name is still not entirely clear, but the unflattering appellation is most certainly not due to any great degree of admiration. Except for a low sandy ridge running north, the Sikeston Ridge, the land was poorly drained and surrounded by vile swamps and marshes. Bears and catamounts prowled the fever-infested cypress forest. Disease was rampant. And in an unmistakable omen for all those bright enough to heed it, the river flooded the settlement the very first winter.

Most of the people accompanying Morgan soon gave up and returned to their homes in Kentucky. Morgan himself followed shortly after, especially once he learned from the Spanish that the land was not actually his to sell. Denied a profit, his interest in the grand scheme

Sikeston Ridge with Spanish land grants (small rectangles). The variable size and random placement of the grants are a constant problem for land surveyors.

waned considerably. Today, his and other Spanish land grants show up clearly along the ridge as it extends north from New Madrid.

To claim land, a settler merely found unoccupied space and petitioned the Spanish for a grant to that parcel, or he first submitted a petition and was granted a piece of land somewhere at the government's option. Often the grant specified only the amount of land, and not the actual location. Naturally, this led to more than a bit of confusion. Because rivers and other natural boundaries were perfect starting points for laying out a claim, few if any of the Spanish grants follow a regular compass-oriented scheme. Like Band-Aids laid across Sikeston Ridge, Morgan's original Spanish parcels stand out clearly against the regular latticework of property lines established by American surveys that followed Thomas Jefferson's purchase of the Louisiana Territory in 1803. Similarly irregular survey lines abound around Ste. Genevieve, St. Louis, and St. Charles. Many of the Spanish grants would be contested when Louisiana became part of the Unites States. The Spanish were terribly casual about surveying and recording land grants and deeds, a troublesome situation further complicated by widespread graft and fraud.



Settlement Proceeds

Meanwhile, New Madrid somehow survived Morgan's departure, at least in spirit, and the area grew quickly to a scattered population of about 1,500. Unfortunately, situated as it was, only 600 yards from the river on the outside of a bend, the town was soon eaten alive as the Mississippi continued its natural meandering. In only 15 years three successive forts and a number of the streets initially laid out by Morgan were gobbled up by the insatiable current. Current topographic maps of the area clearly show the original land grant boundaries - dashed red lines adrift in the middle of the river, or creeping up the Kentucky bank. It should not be surprising that many arriving Americans chose to live elsewhere. By then, Francois Le Sieur had built the fort of Little Prairie at a site to the south of New Madrid, now known as Caruthersville, and a French trader, Louis Lorimer, had established a post to the north that would become Cape Girardeau.

In 1767, the settlement of Carondelet had already been laid out at the mouth of the River des Peres, just south of St. Louis. The little trading post of Les Petites Cotes, "the little hills," later to be known as St. Charles, was established on the Missouri River in 1769, and Florissant, or St. Ferdinand, was founded in 1787. Although under the rule of Spain, virtually all the white inhabitants of Louisiana were French and the whole region remained French in character despite 40 years of Spanish control. Even though Americans immigrated in greater and greater numbers, their initial influence remained slight. Mainly frontiersmen and farmers, they tended to be loners and dispersed widely, Daniel Boone-style. In fact, in the 1790's, Dan'l and his sons were among those accepting Spanish offers of land. The French tended to congregate in villages, and therefore set the social standards.

Throughout this period, the Spanish had been going to great lengths to pacify the surrounding Indian tribes. A steady stream of gifts and friendly invitations to trade were issued over the years to encourage tribes both east and west of the Mississippi to become allies against the British. The British, in their colonies, were doing the same. As a complicated offshoot of the American Revolution, Spain finally declared war on Britain, and the British immediately recruited bands of Indians to raid the Spanish. In 1780, 950 British and Indians from the Menominee and Winnebago tribes of the southern Lake Michigan region initiated a surprise attack that caught the farmers of St. Louis tilling their fields. The Lake Michigan interlopers killed several St. Louisans before being repelled by the 150 citizen-soldiers of the village, aided by new stone fortifications and five cannons, which may have been the beginning of the long-standing Cardinals-Cubs rivalry. The entire contingent of 60 Spanish militia from Ste. Genevieve, trained and stationed in St. Louis to assist in the event of just such an emergency, ran and hid during the attack, while the Spanish governor locked himself in his quarters.

After this victory, the Spanish were able to steal the allegiances of many members of the Iowa, Oto, and Potawatomi tribes from the British. At the same time, because of a shortage of funds and trade goods forthcoming from the Spanish, the attentions of many formerly pro-Spanish Indians reverted to the British. The Spanish began having a difficult time with members of the Missouri and Osage tribes, who in particular preferred dealing with the British. A tall, handsome, and warlike people, the Osage had a rather straightforward attitude toward property ownership. If it was in Osage territory, it belonged to the Osage.

In 1787, in an effort to protect their settlements from the sticky-fingered raids of the Osage, Spanish officials invited the displaced Shawnee and Delaware tribes to Missouri, under the direction of Louis Lorimer, offering them land in the area around the present city of Cape Girardeau. Like the earlier displaced Kaskaskias, these tribes had also been forced from their homelands in the east, although it was now because of expanding American settlements, rather than British colonies. The Spanish encouraged the Shawnee and Delaware to raid the Osage for the next five years, and though never managing a decisive defeat, did manage to keep them at bay. At the same time, Sac and Fox Indians from the Wisconsin region were able to subjugate the Missouri tribe, a dangerous ally of the Osage.

All these tribes continued their traditional hunting practices to acquire food, while augmenting their European material wealth by trading skins, pelts, and meat, which required additional hunting. It was not long before Indian subsistence hunters became true market hunters, supplying game and wild game products via white traders for profit. For a short time, the growing urban populace of St. Louis, now

James Memorial Library - St. James

Market hunters severely depleted Missouri's wild game. Sadly, much of it was wasted because there was no refrigeration.

the center of the fur trade, and other rapidly growing communities depended on wild game provided by Indians for meat. Primarily because of the inordinate amount of attention paid to the trade in furs, the number two industry of Louisiana, the growing number of lawyers, doctors, entrepreneurs, and businessmen supporting the trade and its practitioners could pay scant attention to the production of food, relying on others for their supplies.

Market hunting thrived primarily because of the slow pace of domestic meat production. Even though farms on the loess-covered hilltops and river terraces of the Mississippi and Missouri rivers and their larger tributaries were surprisingly productive, disgorging large quantities of vegetables and produce, meat from livestock was not yet abundant. The use of the surrounding countryside as open range led to considerable losses of cattle, sheep, goats, and hogs due to straying, accident, disease, and Indian theft. Rare at first, white market hunters would soon become a common feature and would more than replace the Indians as suppliers of meat, but especially hides and furs during the next 30 years.

Among farmers, the French were particularly lackadaisical about tending their fields and animals, letting nature more or less take its course. American settlers generally cared for their crops more fastidiously, and they reaped much larger harvests for their trouble. The steady influx of American farmers from the southeast soon made agriculture the number one industry, reducing somewhat the pressure on native game, at least for meat. Even as late as 1800, however, few farmers showed much interest in fertilization, soil conservation, or other stewardship practices. Land was simply too abundant and too cheap to show much concern over such trivial matters. In the late 1840's, however, the arrival of immigrant farmers from Germany, where land was already scarce and conservation necessary if profit was to be made, brought new and more efficient agricultural methods to the state.

Early European populations settled mainly in eastern Missouri, restricting their impact on wildlife and forest resources. Trade with resident tribes converted the Indian into a profit-motivated market hunter. Coupled with the introduction of eastern tribes, this markedly increased the stresses on natural resources. Continued American immigration would soon stretch those resources to the breaking point.

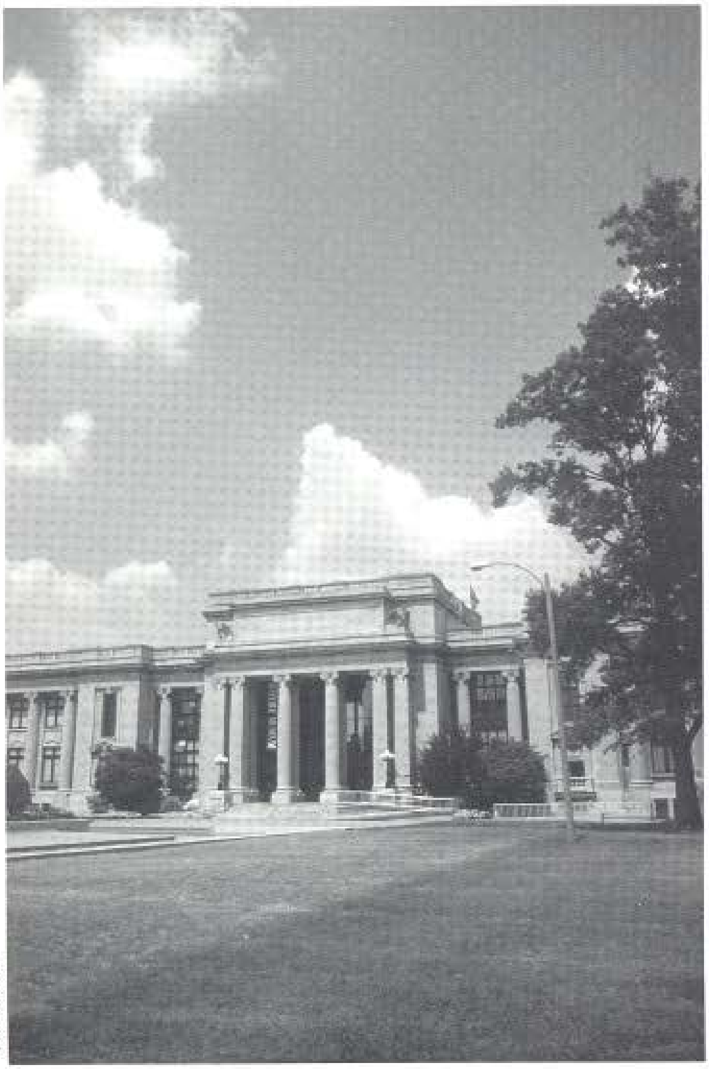
The Americans Take Over

Under Spanish rule, American influence in Louisiana grew steadily in the last decade of the 18th century. At the same time, Napoleon's rise in France was about to send Louisiana on a wild series of events that would forever alter its landscape and natural history. Napoleon coveted Louisiana as the perfect source of food and goods for his growing sugar empire in the Caribbean. In 1800, at his urging and by secret treaty, Spain relinquished her control of Upper Louisiana, a vast region lying north of the present states of Louisiana and Texas. Napoleon now had his personal granary. He initially intended to administer this new empire from the Caribbean island of Haiti, but his forces failed to quell a black revolt there and he was deprived of his necessary base of operations. Napoleon began to rethink his position.

A renewed threat of war with England, the constant infiltration of Americans into Louisiana, and the need for continued American friendship in the face of the British threat, brought him to the conclusion that his dream of conquest might be unrealistic. Recognizing that Americans, by their continued immigration, were slowly gaining control of Louisiana anyway, and to cut his losses, Napoleon decided to sell the territory to the United States. American control of the region would at least head off further British expansion. Spending only 15 million dollars, the President of the United States, Thomas Jefferson, bought 830,000 square miles of North America, neatly doubling the size of his nation.

By 1803, when the United States actually gained control of Louisiana, Americans already constituted 60 percent of the 10,350 Missourians, and another 15 percent were black and Indian slaves. Except for Indians and Indian traders, few people braved the forbidding wilds more than a few miles beyond the reassuring banks of the Mississippi River. Tiny La Charette in Warren County was the westernmost settlement encountered by Lewis and Clark on their monumental journey of exploration in 1804. Despite the rapid rise in American settlement, Missouri still remained largely unplowed and uncleared.

The Jefferson Memorial, in St. Louis' Forest Park, commemorates Thomas Jefferson's role in negotiating the purchase of the Louisiana Territory.



Jon Hawker

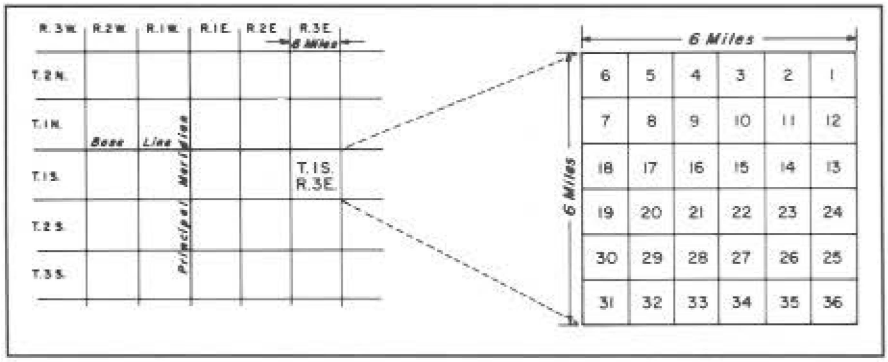
Outside the two population centers of St. Louis and Ste. Genevieve, European and American immigrants were thinly scattered and were mainly clustered into a "lazy T" that was centered on the confluence of the Missouri and Mississippi rivers. The development of natural resources had not yet progressed enough to disperse settlers. One major salt work was operating on Saline Creek, near Ste. Genevieve and, until an Indian raid forced its abandonment, another had been built as far north as the Salt River, in Pike County. Both operations boiled creek or river water to concentrate the dilute salt solution they contained. Vital to settlers, salt was needed for livestock and curing hides, as well as for dietary needs.

Some distance to the south, the original cluster of French lead mines, plagued by a constant string of claim-jumping, violence and legal disputes, somehow continued to produce large amounts of the metal. Lead miners only worked three or four months out of each year, however, so settlement of the region did not advance swiftly. The workers and engineers maintained permanent residences back in Ste. Genevieve or elsewhere along the Mississippi River. In all, movement into the interior of Missouri was slow at first.

Bringing Order Out Of Chaos

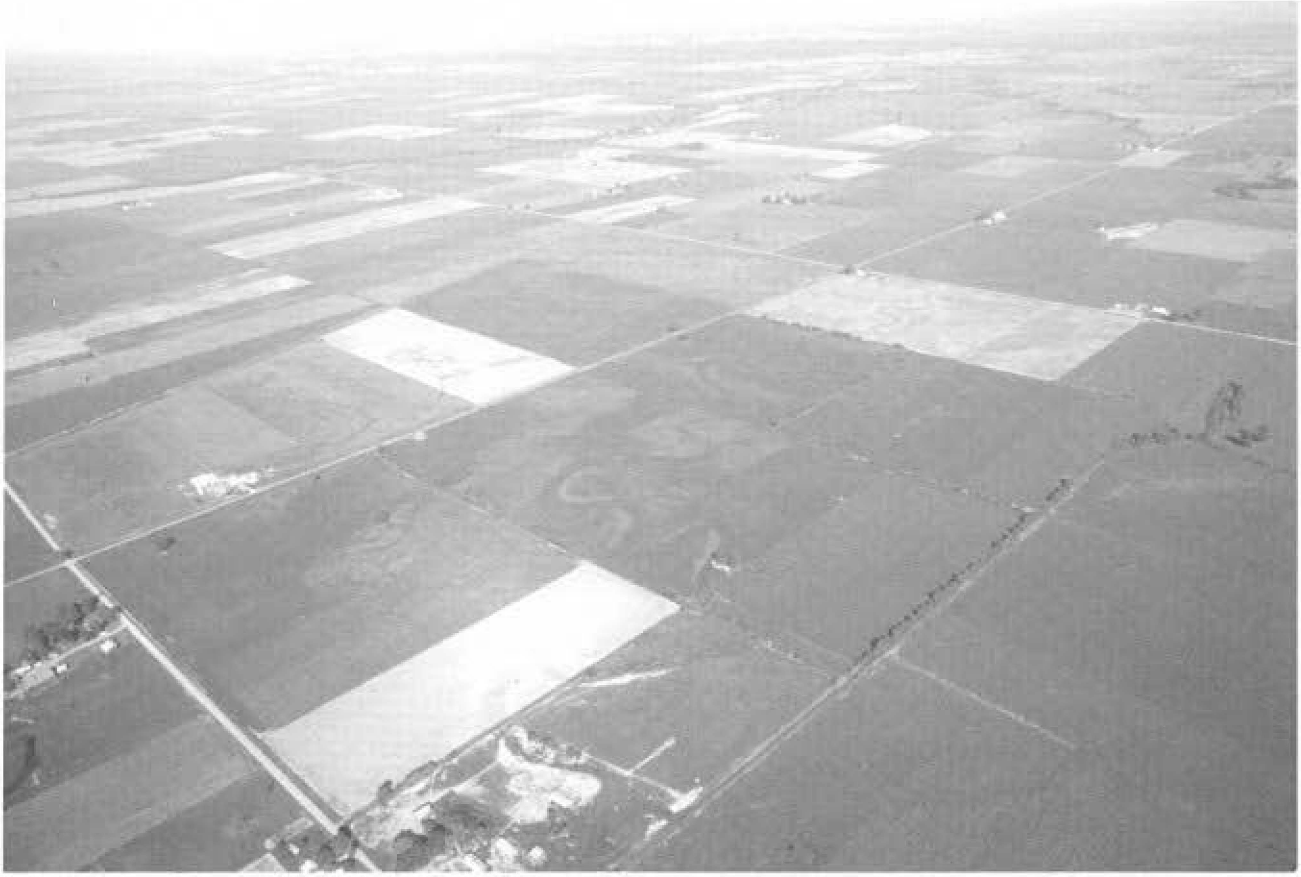
The United States had already established a formal surveying system before purchasing Louisiana, in 1785 and 1787, when Congress passed two land ordinances. The second of the two ordinances allowed the political organization of newly acquired lands bounded by the Mississippi and Ohio rivers and the Great Lakes into territories, the first of which would be called the Northwest Territory. When they met certain criteria, territories could later petition for statehood. This ordinance would apply to Missouri lands in 1805, when Louisiana was granted territorial status. Of more relevance at the moment, however, was the first ordinance, which authorized a systematic survey and sale of new federal lands in the Northwest Territory. The original colonial properties, laid out as if by random blasts from a blunderbuss, were a crazy-quilt of intersecting boundary lines, much like those encountered among French and Spanish grants in Missouri. With the new territories, Congress had the opportunity for a more measured approach.

Beginning just west of Pittsburgh, Pennsylvania, the Northwest Territory was divided into 36 square-mile townships, 6 miles on a side. Each township was then divided into 36 sections of one square mile or 640 acres each. These 36 sections were numbered consecutively, row by row, from the southeast corner to the southwest corner - sections 1 through 6 up the first row, 7 through 12 down the second, 13 through 18 up the third, and so on. The first north-south row of townships along the Pennsylvania border was called the first range, and all westward ranges of townships were then numbered consecutively from that range. The east-west rows of townships were then also numbered consecutively, either north or south of a geographer's base line. Thus a particular section or square mile of land could be labeled Section 12, Range 6, Township 5 North, or Section 31, Range 23, Township 9 South, and so on.



6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Idealized government land divisions. This diagram illustrates the relationship of fractional land divisions in sections to townships and ranges.



Jon Hawker

Wherever the land is flat, the survey lines are the most obvious feature of the landscape, dividing farmlands into a checkerboard pattern.

Here in the Midwest, a similar systematic survey was authorized for the new Louisiana Territory in 1806. There are a few differences in our property descriptions, however. In the new territory, ranges were numbered east and west of a new base line set approximately on the Fifth Principal Meridian. Louisiana townships were laid out north and south of an arbitrarily chosen base line that now divides Phillips and Lee counties in Arkansas. Finally, the sections of each township were numbered from the northeast corner to the southeast corner, back and forth across the township in east-west rows. This meant that Missouri properties would all be found in townships numbered from 16 to 67 North, and in ranges from 18 East to 42 West of these new base lines. Other than these three minor adjustments, essentially the same surveying system was used east and west of the Mississippi. In either territory, wherever title to the land was already firmly held, such as undisputed Spanish land grants in Missouri, the earlier survey lines were honored; hence, the strange geometric shapes bounded by property lines in eastern Missouri, a few of which are found as far as 60 to 120 miles inland.

The original Louisiana land survey has been instrumental in the development and appearance of the Missouri landscape ever since. A checkerboard of textures and colors - varying with the region and the season - now covers the entire Midwest, wherever the topography allows farming. In addition, most of our roads, built along property boundaries, doggedly follow the east-west or north-south survey lines. The regular and predictable latticework of fields, highways, and feeder roads is especially apparent in our northern and western prairie counties where, as a result, getting lost is seldom possible. The geometric partitioning of the prairie afforded by the American land survey eased settlement and hastened the demise of the natural, never-geometric landscape.

The transportation system in the Ozarks is a creature of a different stripe. Although remote in time, the Tertiary uplift and erosion of the Ozarks forced early road-builders to follow game and Indian trails along ridges, creeks, and rivers. As a result, the first Ozark highways and railroads, built before the days of heavy earth-moving equipment, meandered as badly as the drainages. The steep, rocky hillsides also discouraged or even precluded farming; hence there is only the suggestion of a checkerboard pattern in the rugged, forested Ozarks. The aerial appearance of the land today reflects the regional settlement pattern of the 1800's.

The original land survey records for Missouri are maintained in an archival vault at the Department of Natural Resources' Division of Geology and Land Survey in Rolla. The notes made by surveyors in the early 1800's are remarkably detailed, with descriptions of forests, rivers, and prairies that have been used to make maps of presettlement landscapes.

Only since the advent of heavy construction equipment have wide, reasonably straight roads been possible in the hilly Ozarks such as on U.S. Highway 21, Jefferson County.

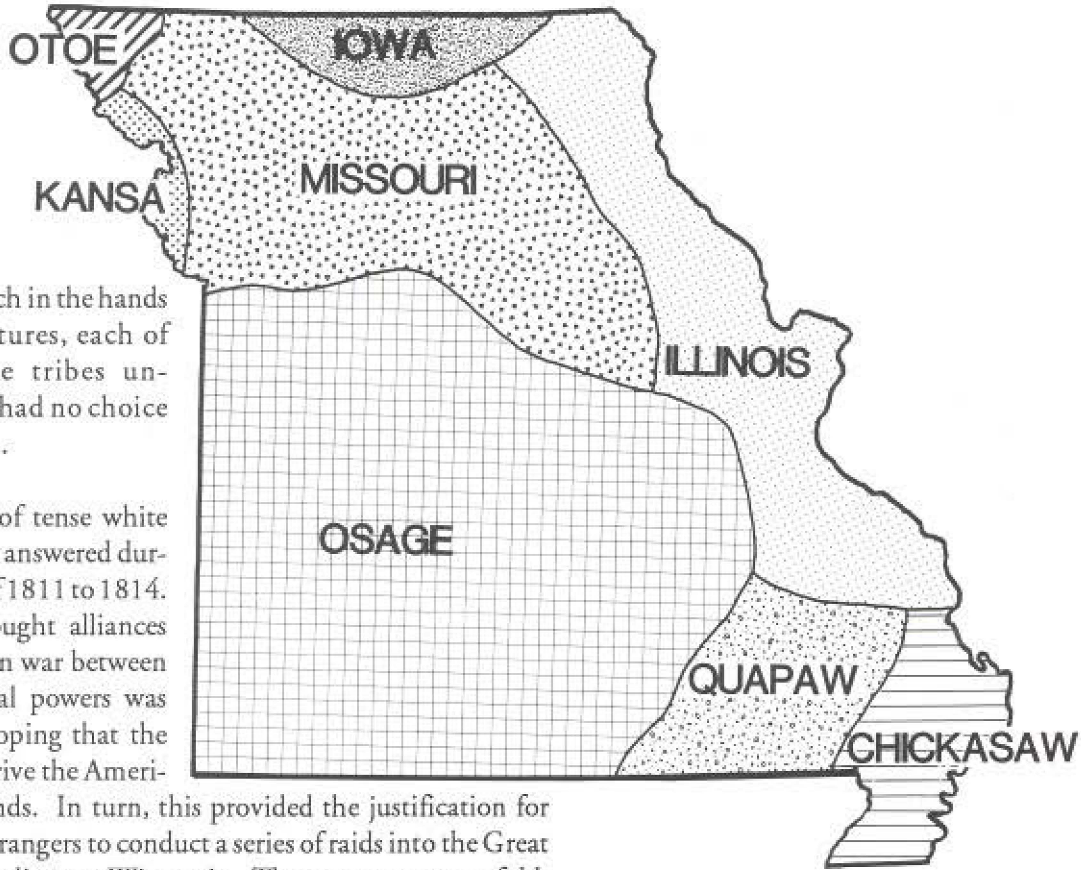
Jon Hawker

Friction With The Indians

The increase and spread of Missouri's immigrant population shifted dramatically into high gear once Louisiana was in American hands. After 1804, the territory was suddenly flooded with settlers, multiplying her population six times in just 15 years, then doubling it again and again in each of the next four decades. As Americans poured in it was only a matter of time before clashes with the Indians would intensify. The Indian population was also at its peak at this time, with members of the Osage, Iowa, Fox, Sac, Kickapoo, Kaskaskia, Miami, Winnebago, Potowatomi, Kansa, Omaha, Ponca, Pawnee, Delaware, and Des Moines Sioux tribes. A number of minor incidents occurred as a result of lawless actions by individuals on both sides. These were immediately exaggerated into "raids," "massacres," and "attacks," or as "brave defenses." To be sure, there were serious Indian threats and depredations, but for most settlers the threat was often blown far out of proportion to reality. Between 1808 and 1812, more than half the population had only recently arrived in the West and had never personally experienced Indian difficulties, nor were they likely to. Nonetheless, many newcomers fed on freely circulating rumors and on published accounts describing fearful atrocities and went into a panic.

The Americans made every attempt to lay the blame on the inherent savagery of the Indian and on the greed of English traders to the north. In truth, British Canadian agents did go to great lengths to foment unrest among the Indian tribes of the territory in hope of securing a much larger trading network. Their activities increased as political tensions between the Crown and the fledgling United States government worsened for a host of other reasons.

In reality, the underlying cause of Indian discontent was the constant infiltration of white settlers into Indian territory. Again and again Indian tribes had been pushed from one newly-guaranteed homeland to another, always under the protection of another treaty, only to be pushed out once more. Virtually all of the Indian tribes involved were forest cultures. Now with their backs to an alien prairie



Missouri's Indian tribal areas prior to settlement.

habitat, still very much in the hands of fierce plains cultures, each of the many separate tribes undoubtedly felt they had no choice but to take a stand.

The demands of tense white residents were largely answered during the Indian wars of 1811 to 1814. Many tribes had sought alliances with the British when war between the two international powers was declared in 1812, hoping that the British would help drive the Americans from Indian lands. In turn, this provided the justification for Missouri militia and rangers to conduct a series of raids into the Great Lakes region, from Indiana to Wisconsin. The purpose was twofold: quell the central sources of Indian disturbance and thwart British advances into the Northwest Territories. None of the military engagements were particularly successful nor decisive.

Finally, the threatening situation became almost desperate for pioneers in Missouri Territory and, for a very brief period, immigration came to a standstill. Some discouraged settlers returned to the East. Then suddenly and unexpectedly, Great Britain ended hostilities in 1814. Having won the conflict in Europe, the island empire decided to concentrate on industrial development as a means of gaining world dominance, rather than costly wars. The sudden loss of their principal ally threw the dumbfounded Indians into disarray. Uncertain which course of action to take next, their intertribal cohesiveness quickly disintegrated. The powerful coalition forged by hatred of a common enemy was shattered. Each tribe opted for whatever solution seemed best for its own members. During the course of many negotiations over the next year, most hostile tribes concluded separate agreements with the United States. Immigration, slowed to a trickle by the combined fear of British invasion and Indian attack, now assumed flood proportions.

The threat of Indian attack and the War of 1812 briefly slowed immigration into Missouri in the decade following the Louisiana Purchase, but these temporary setbacks were quickly overcome. Development of the territory, soon to be a state, would now proceed unchecked.

Statehood

By 1820, the threat posed by the Indians had totally vanished, although they themselves had not. The Osage still inhabited much of the western Ozarks, Kickapoos had moved to an area around the Pomme de Terre River, the Shawnee and Delaware remained around Cape Girardeau, and another band of Delaware lived on the White River. Although permanently settled outside the territorial borders, many members of the Missouri, Iowa, Kansa, Sac, and Fox tribes continued to hunt in northern Missouri for some time. The mushrooming white population of Missouri, initially ingrained with a view of the Indian as savage and bloodthirsty, slowly came to accept the basically peaceful intentions of the red man. Fear began to be replaced by other emotions. The evolving attitude was fostered in some quarters by a tiny hint of guilt about the mistreatment of the Indian over the years. Among missionaries and some others, this was combined with the rebirth of an earlier philosophy that had overly romanticized the "noble savage." Bigotry, as might be expected, remained a potent threat on both sides of the issue.

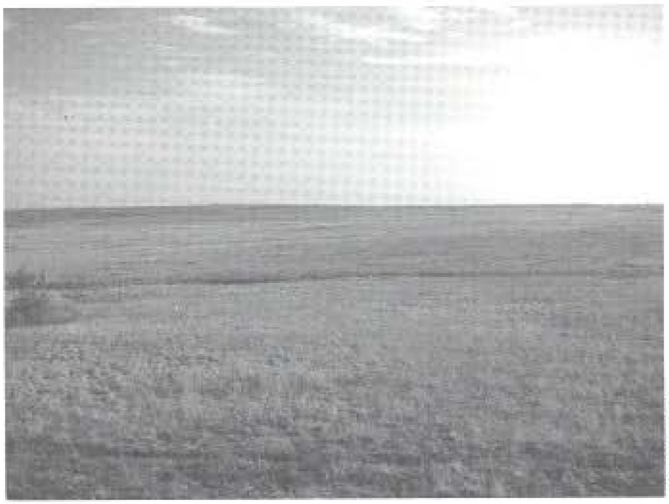
Though peaceable, relations between white and red never really stabilized because of the inevitable clash of two such completely alien lifestyles. Bred to a totally unshackled life of subsistence hunting and free to travel anywhere within their broad tribal territories, the older generation of Indians could not accept what they viewed as the harsh restrictions, the almost prison-like ways of white society. They considered whites to be willing slaves to an inflexible economic system. White settlers, generally endowed with a powerful work ethic, considered the Indian to be shiftless and lazy, untrainable and unable to hold a steady job. More importantly, no matter how much territory they usurped, the whites clearly continued to lust after Indian lands and demanded the complete removal of Indians from any area where the slightest friction developed.

Admitted to statehood in 1821 with just over 100,000 inhabitants, Missouri skyrocketed from 23rd among 24 states in population to 8th among 33 states in 1860! The immigrants surged west along the Missouri River, establishing Jackson County in 1826. From the Big Muddy, settlers poured up the Chariton, Grand, Platte, and Osage river networks, and by 1851, 106 counties had been laid out and organized politically. The 1850 census showed that there were now over 260,000 Missourians, two-thirds of whom had come from Kentucky, Tennessee, North Carolina, and Virginia. A lack of good farmland would delay the formation of the remaining eight Ozark counties for a short time, but by the time of the Civil War, the state was essentially in its modern configuration.

Some Little Houses Ain't Much Better Than No Houses At All

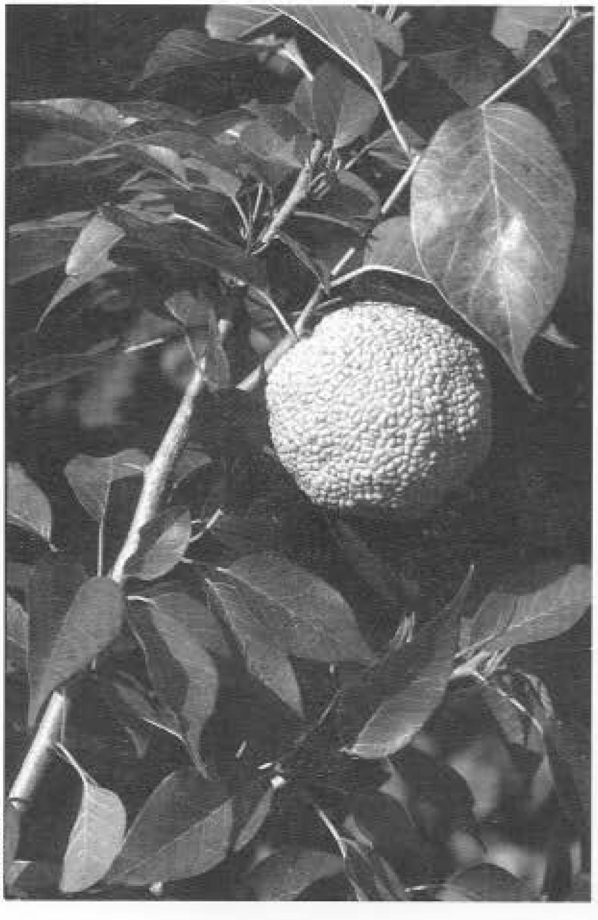
While the river bottoms and adjoining hilltops of the expanding "lazy-T" centered on east-central Missouri quickly filled to capacity, the prairie lands of northern and western regions were generally scorned because they were considered to be unsuitable for agriculture or settlement. Although some Missouri grasslands were being plowed as early as 1819, broad prairies meant little water, no timber for firewood, buildings or fences, and no acorns for hogs, which depended on the nuts for a yearly boost of protein, oil, and starch. Indian and lightning fires still raged unchecked every year and the soil was often underlain by a hard, resistant claypan. The winters were intensely cold with drifting snow, while summers were ungodly hot. Not a fun place to live. The smaller tracts of prairie on the ridges of eastern Missouri, such as those on the loess-draped hilltops around the city of St. Louis, were quickly and easily conquered. This naturally open ground, ringed with nearby woodlands and adjacent to reliable creeks, provided the essentials lacking on western and northern prairies. They must have seemed like a sign from God to pioneering farmers and were soon producing abundant harvests. Early in the 19th century, however, the vast inland sea of grass was a different matter entirely.

The prairie vista, as seen here at Prairie State Park, was a frightening sight to settlers reared in landscapes without distant horizons.



Jon Hawker

Pioneers had to make considerable adjustments in their lifestyles if they were to fit into the strange new grassland world. In the deepest prairie lands, largely to the west of Missouri, fuel for winter heat and cooking was available only in the form of dry buffalo or cow manure. These "buffalo chips" were collected in baskets each day by scavenging youngsters. Dwellings were small one-room affairs, windowless, or with one or two tiny portholes for light, built of sections of sod cut from the surrounding prairie. Called "soddies," the bleak residences had dirt floors and often only a sheet of canvas for a door. Men and women aged quickly and died young under the extreme hardships imposed by the environment. Many retreated before the constant assault, plagued by loneliness and homesickness. Many others persevered to see the many problems overcome and the battle against nature won.



Before wire fencing, hedgerows of Osage Orange were the chief means of cordoning the prairie.

Jon Hawker

Throughout the grassy areas of the Midwest, the problem of fencing was initially solved with the cultivation of the Osage orange, or hedge apple tree. This native tree adapted easily to cultivation and lush hedgerows popped up wherever farmers settled. The proliferation of dark green hedging sliced one secure section of living space after another from the windswept prairie land. The dense foliage quickly killed the grass for a distance of 10 or 20 feet on each side of the planted row, shielding buildings, crops, and cattle from wildfire. The tangle of nastily thorned branches effectively restrained livestock and, in the territories farther to the west, helped hold marauding Indians at bay. At the same time, the greenery slowed the ceaseless prairie wind, reducing crop damage and the drifting of winter snow.

Osage orange trees grew fast and had to be periodically topped to prevent them from robbing the moisture and fertility from a wide swath of farmland, but the trimmings provided a steady supply of wood for small articles or the hearth. The calming effects of an Osage orange hedge must have been priceless to a forest- or savanna-bred people, ill-prepared psychologically for horizon-to-horizon vistas devoid of landmarks. Each hedge that went up not only added a recognizable landmark, it placed the domineering mark of civilization in a featureless wilderness landscape. In addition to its benefits to humans, the hedgeapple network afforded living and breeding space to innumerable birds and small mammals. Unfortunately, because Osage orange roots spread far from the trunks in their quest for water, a sizeable percentage of land was eventually rendered unplowable. Beginning in the 1850's, the demand for increased yields began a trend toward replacement of the picturesque hedgerows with wire fencing. Yet even today scattered remnants of these original property lines still criss-cross Missouri farmland.

Susan Dunn

Even today scattered hedgerows of Osage Orange can be found criss-crossing Missouri farmland.

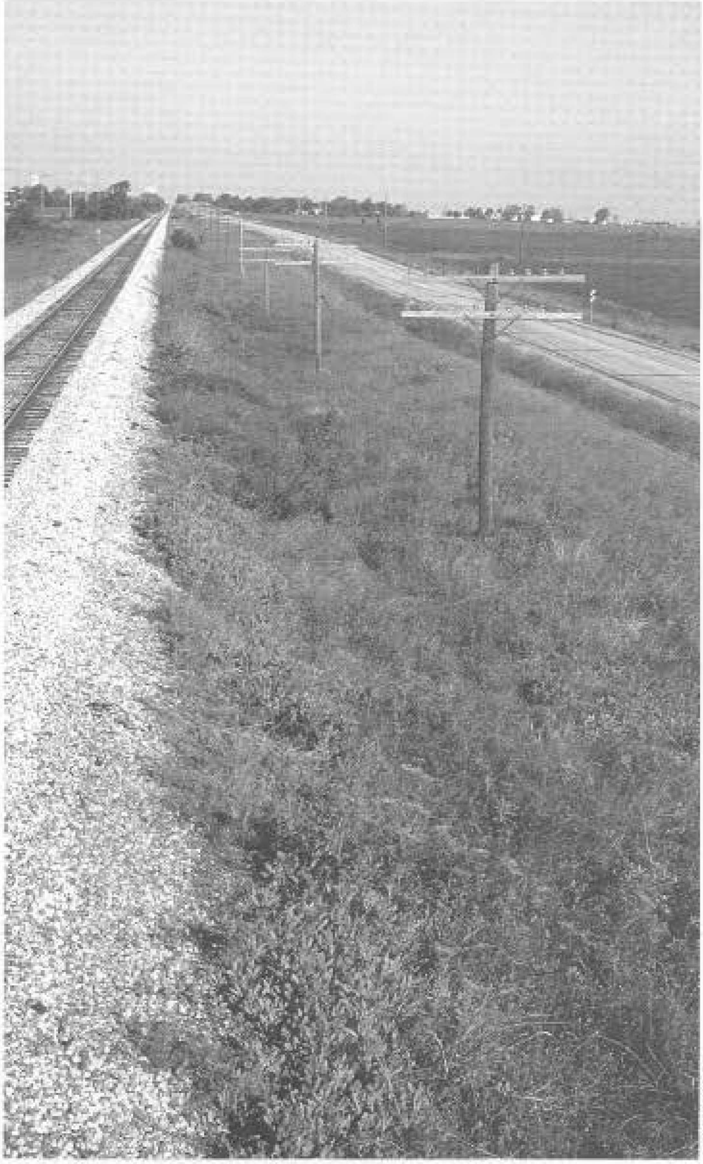
Osage orange was not the only woody species planted on grasslands. Wherever they settled, farmers established woodlots and windbreaks around the house and barn using a variety of drought-resistant trees and shrubs. Arbor Day, a national day of tree planting now observed on different dates in different places, actually began in 1872 on Nebraska prairies, where they really needed trees. Early pioneers planted whatever was available locally, such as juniper or eastern red cedar, elm, or catalpa. As trade routes were established, the influx of exotic species from Europe or Asia became more obvious as ornamentals and then as "working" plantings around homesteads. Even without planting or encouragement, woody growth increased spontaneously following settlement. As prairie farming progressed, Indian populations were driven out, roads and hedgerows were laid out, and plowing increased, all of which diminished the incidence of fire. As the threat of fire was checked, native woodland began reclaiming lands overrun by prairie during 10 millennia of burning. Old grasslands sprouted saplings to become savannas, and old savannas filled with underbrush became forest. Trees and shrubs crept out from streambeds to line fence rows, roadsides, railroad rights-of-way, barnyards, old cemeteries, and any other land not plowed or intentionally burned. In fact, Missouri's prairie counties are the only regions of the state where forest cover was actually on the increase during the second half of the 20th century. Today, a sense of grassland, a prairie image, cannot easily be conjured in Missouri. Especially in the glaciated region, the biome has been completely obliterated and replaced by brushy farmland.

In the southwestern part of the state, however, where soils were thinner and plowing was often less productive, one can visit Prairie State Park or any of another dozen or so sizeable tracts that preserve and maintain the essence of our grassland heritage. In addition to woody encroachment, native grasslands also succumbed to invading herbaceous species. The intentional seeding of bluegrass, for instance, a practice that would rapidly displace native grasses and wildflowers, began as early as the 1830's. Some settlers scattered handsful of bluegrass seed from saddlebags wherever they traveled, spreading cultivars far and wide. This dubious practice theoretically offered cattle wholesome green pasturage in the winter when Missouri's warm-season native grasses had withered. Although still nutritious and valuable, the dead brown thatch was an alien scene for farmers familiar only with the perpetually green pastures of cool season grasses in cultivated European fields. As they cast the seeds of bluegrass and other choice European forage plants, such as clover and sweet clover, the seeds of a plethora of other Eurasian pasture plants and weeds were spread as well. Many had an august heritage, arriving in the bedding, straw, hay, and manure of the Mayflower, then spreading west along trails, paths, and rivers. These immigrants have become the characteristic vegetation of Missouri roadsides, old fields, and riverbanks.

After the first few discouraging years on the prairie, farming became surprisingly prosperous. Once eastern forest cultivation methods were adapted to this new environment, the establishment of row crops went extremely well. Unlike forest clearings, plowing was not hampered by stumps and the underlying soil was deep and rich. Even so, new fields were not particularly productive in their first years. The stubbornly resilient prairie sod struggled to maintain possession and quickly regrew. It was finally defeated after 1837 with the help of a new self-scouring plow invented by an Illinois blacksmith named John Deere. Earlier plows were made entirely of cast iron and the sod stuck to the moldboard, the curved part that turned over the soil. Deere began experimenting with strips of tempered saw blade welded to his plowshares so the sod would be cut cleanly and flip over neatly. Within 15 years, his plow had revolutionized grassland agriculture. By 1856, the Deere factory in Moline was turning out 10,000 such implements a year, a near-perfect reflection of the pace of prairie settlement. The improved plow was followed by improvements in or the invention of many other farm implements, such as seed drills, reapers, and threshers.

The soils of the rocky Osage Plains were rich enough to allow some plowing, but were just thin or rocky enough to spare a section here, a quarter-section there, and a half-section back over yonder. These native pastures provided forage year-round and abundant hay crops with little investment of time or labor. Passed from father to son, they became part of each farm family's heritage. Unfortunately, these family prairies have also come under assault. As children moved away to seek employment in urban areas, more and more small farms passed into the hands of large family operations and corporate holdings. The oil crunch of the 1970's raised the price of fuel, fertilizer, and other farm chemicals tremendously, leading to a rise in the price of corn, soybeans, and wheat. Profit-making in the 70's and 80's meant bringing previously unplowed, often marginal land into production. Lacking a sense of family heritage and faced with mounting bills, managers of large holdings were forced to plow prairies that had never been plowed before. They simply could not afford to let the land be.

Virtually the only prairie habitat remaining in northern Missouri is found along railroad rights-of-way and pioneer cemeteries.



Jon Hawker

In contrast, virtually all of northern Missouri had been planted in domesticated grasses and crops by the turn of the 20th century. The tills and loess of the glaciated prairie were just too productive not to plow. If all the remaining native prairies north of the Missouri River could be gathered into one place, they would not fill a single section of land. The largest patch - the University of Missouri's Tucker Prairie - may be seen from I-70 20 miles east of Columbia, but a lovely narrow strip separates the railroad from Missouri Highway 19 between Martinsburg and Montgomery City. Now, less than one-tenth of 1 percent of the original native prairie of Missouri remains, most of it on the thinner grazing soils of southwestern Missouri, derived from Mississippian and Pennsylvanian sandstones, limestones, and shales. Because of their rich, stone-free soils - a gift of the glaciers - Missouri's northern counties are no longer mantled by amorphous masses of greens and yellows that vacillate indecisively from season to season; instead they sport a geometric quilt of patent greens and browns related more to economics and plowing and planting schedules.

While the small forest-bordered prairies of eastern Missouri were quickly brought into cultivation, extensive grasslands in western and northern parts of the state resisted settlement. New farming methods and new lifestyles were necessary to overcome the alien landscape, but once begun, farming proved immensely profitable.

Between A Quake And A Soft Place

In the swampy lowlands of southeastern Missouri, settlers encountered a totally different set of problems than those facing folks out on the prairies; but they also had a few advantages. For example, the first pioneers in the Bootheel had access to small patches of open sandy prairie and savanna along the high, dry river terraces and ancient Pleistocene ridges. Indians had lived on and farmed these sites for centuries; consequently the sod was thin and the dense bottomland forest did not have to be removed prior to planting. Everywhere else, however, settlement was virtually impossible. The oppressive heat and humidity; the ravages of mosquitoes, fevers, bears, and panthers; the constant flooding; these and other features of the dismal region kept settlers at a distance. Even worse, in December of 1811, the first of a series of earthquakes struck the Bootheel that would turn out to be the most powerful ever recorded on the North American continent. During the next three months, three major quakes, each exceeding an estimated 8.4 on the modern Richter scale (specifically 8.6, 8.4, and 8.7; worldwide, the greatest earthquakes ever recorded anywhere, ever, reached 8.9!), were felt from North Carolina to Canada. Fifteen large aftershocks rattled buildings as far as 750 miles away and thousands of small but detectable quakes threw the Mississippi Lowlands into turmoil for several months.

All of the original prairies of Missouri's Bootheel were plowed shortly after settlement. To see what they must have looked like, one must travel south to Arkansas' Grand Prairie refuges.

Jon Hawker

Huge areas of swampland rose and their waters drained away. Equally large expanses of high ground sank and were inundated. Uncountable numbers of cracks and fissures of varying depths and widths slit the region, some running for miles. Fountains of gas and water, called blows, blasted sand and coal-like lignite from deep entombment to heights of 30 feet or more. Individual trees were ripped up the middle and entire forests sank or were tossed to the ground in a tangled heap. Hundreds of thousands of acres of forest were destroyed. Domestic and wild animals went absolutely crazy, running pell-mell through farms and small settlements. Bright lights of unknown origin flashed through the night sky, illuminating the frightening scene.

Along the Mississippi, banks collapsed and trees fell into the stream by the thousands. Whole islands sank, and in places, surges of water rose, swelled upstream for a time, then drained quickly away, carrying everything before them. The impression was left that the Mississippi had actually flowed upstream, and indeed it did for a time. Logs that had lain on the bottom for centuries were released from burial, floated off, and helped choke the river. Two new waterfalls, or more accurately rapids, were created in the Mississippi near new Madrid, each with a total fall of about 20 feet over a distance of 2 miles.

For the towns of New Madrid and Little Prairie, both located near the epicenter of the later and more intense disturbances, the devastation was total. While chimneys fell and foundations cracked at Cape Girardeau upstream, little major damage occurred there. At the doomed villages downstream the riverbanks sank disastrously. Little Prairie was instantly and completely wiped off the map by the flood that poured in. New Madrid, originally built 25 feet above waterline, dropped to within 10 feet. What little survived the actual quakes was swept away by the spring floods of 1812. Of course, the loss of the misplaced town to the gouging current of the Mississippi was inevitable anyway; the subsidence merely hastened its demise. Today's New Madrid is due north of the original site. The site of old New Madrid lies approximately in the middle of the river, just about where a new sandbar and island have been cast up by the current during the intervening 170 years.

Not many people died as a result of the quakes. There were only about 3,000 people living in the Bootheel at the time, and they were mostly scattered on small farms. Deaths were generally a result of drownings when water swept over the land, or when riverboats were swamped by the turbulent river. Most buildings were of log or frame construction and were somewhat forgiving of a good shaking, although all the area's chimneys had fallen during the weaker early tremors. Actually, by the time the major earth quakes occurred in January and February of 1812, totally destroying every structure, most people had already fled in terror to the highlands, or across the river to Illinois, Tennessee, and Kentucky. Participation in local religious services boomed beyond any preacher's wildest dreams.

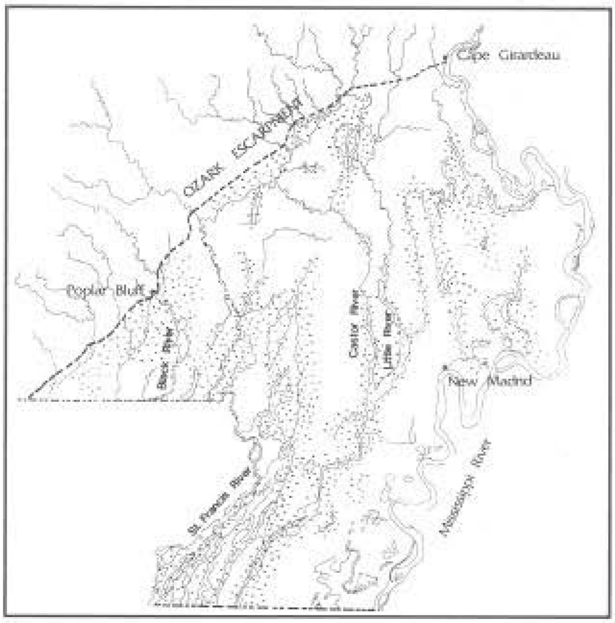
Time has healed most of the superficial damage caused by the New Madrid earthquakes. The cracks and fissures are long gone, forests have regrown where their predecessors fell, and the river has erased all signs of its dramatic channel alterations. The uplift of sand and gravel that produced its impressive, though short-lived rapids, was quickly relevelled. However, some effects are still evident. Reelfoot Lake, in Tennessee, was one of many new lakes created by the quake, and many places in the Bootheel, such as in the vicinity of Sikeston, still display huge patches of sand blasted to the surface by the strange blows of gas, water, and earth. Most of this episode in the history of the New Madrid Seismic Zone now resides fitfully in history and legend, but the restless earth waits.

In the aftermath of the quakes, development of the region was retarded for a decade or two, and has been slow ever since. Land speculation became rampant when the federal government stepped in and offered new land elsewhere in the territory as compensation to those who had suffered property losses. So many fraudulent claims were filed by early forerunners of the carpetbaggers that the government was forced to back off and let the clamor die down; this threw the additional monkey wrench of questionable ownership into the slow workings of recovery. It would be nearly a century, after the great swamps were drained, cut, and burned at the beginning of the 20th century that the bulk of Bootheel land would be converted to agriculture. Until then, it remained the last bastion of true Missouri wilderness, free-roaming bears, and mammoth trees.

The vast cypress swamps of the Missouri Bootheel, such as this remnant in Mingo National Wildlife Refuge, discouraged settlement.

Jon Hawker

The process of draining the Southeastern Lowlands was late in coming, largely because of bureaucratic buck-passing between county, state, and federal govern-



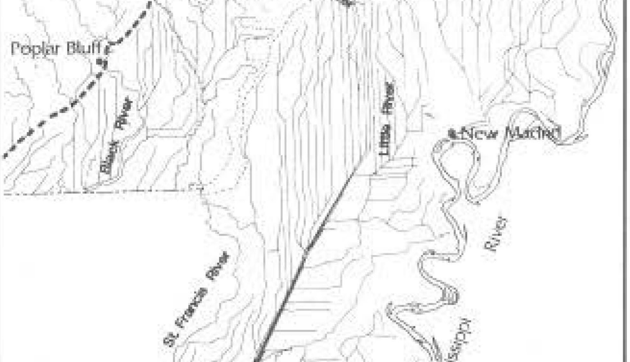
The Missouri Bootheel prior to drainage of the swamp lands was a vastly different place from the farmlands of today. This map shows the original river systems and their associated wetlands, before drainage in the 1900's.

ments - no one really wanted responsibility for the lowland swamps. Eventually, control of most of the land passed to the county level, although all three levels participated in the ditch-digging operations. Once underway, the drainage proceeded with an efficiency alien to bureaucracies.

Originally, a lazy network of meandering Bootheel rivers passed pell-mell through a hundred lakes and swamps of various sizes strewn across the Lowlands. Some were broadenings of the streambeds themselves, while others formed in old cut-off channels called **oxbows**. Two of the largest were at the southern ends of the Castor and Little rivers. Like long, slender bays, these flowed almost casually into Big Lake, an enormous swamp across the border in Arkansas created during the 1811-12 quakes. Within 10 years after ditching began, nearly all the stagnant waters of the central Bootheel were collected and sent on their way to that huge Arkansas swamp. Today, that swamp is the central feature of the Big Lake National Wildlife Refuge. Along the northern end of the Bootheel, where rivers entered from the Ozark uplands, water was collected in a large "Headwater Diversion Channel" that carried the drainage around the Bootheel, either east into the Mississippi River or southwest into the St. Francis. These routes took advantage of the ancestral Mississippi channel that lay between the Ozarks and Crowley's Ridge. Drainage into the St. Francis River at the south end of the diversion channel - barely perceptible under the best of circumstances - was interrupted in the late 40's at Puxico to meet the needs of migratory waterfowl passing through Mingo National Wildlife Refuge. Upstream, the flow in the channel is equally indecisive. On the other side of Crowley's Ridge, with their heads cut off, the undernourished channels of the Castor and Whitewater rivers now writhe impotently through soybean and cotton fields. This drainage of the Bootheel was a colossal project and necessarily systematic.

Drainage districts were established in each county, often by bond issue, and landowners paid from $2.50 to $4.00 per acre to finance the system of feeder ditches, collection channels, and main diversion canals necessary to run Missouri water hundreds of miles downstream into Arkansas. As the land was drained, lumber companies pursued like hounds on a scent, purchased hundreds of thousands of acres of land, and removed hundreds of

Few Bootheel streams retain their original channels; most have been converted to straight ditches.



millions of board feet of bottomland timber each year. Within 10 years, most lumber companies had run out of trees and went bankrupt. Today, the few patches of forest and swamp that managed to somehow survive the original drainage continue to wither at a depressing rate as bulldozer and fire open increasingly marginal flood plain to periodic crop production possible only in dry years.

Jon Hawker

Practically no virgin cypress swamp exists in Missouri, although some individual trees have escaped to remind us how vast the habitat must have been.

Not all of the Lowlands was originally timbered. As described earlier, large tracts of prairie and savanna lay in strips along the higher river terraces and natural levees, and in some lowland situations. At the time of settlement, for instance, 18,000 acres of Mississippi County and 2,000 acres of Dunklin County were prairie. Sikeston Ridge was a prairie-savanna mix, and was immediately gobbled up by settlers because of it. With their well-drained and open position, such prairies were prime agricultural land and disappeared rapidly. Close to sources of wood and water, they were the best the Bootheel had to offer, and the first to go. While Missourians have managed to preserve a few thousand acres of Bootheel forest within Big Oak Tree State Park and Mingo, none of Missouri's bottomland prairies remain; the nearest remnants are at Grand Prairie in Arkansas.

Settlement in the Bootheel was slowed by the New Madrid earthquakes of 1811-12, by widespread confusion over legitimate land claims, by a good deal of bureaucratic fumbling, and most importantly, by the land itself; a broad series of wet, lowland forests, and swamps. Once drained, the land released a phenomenal wealth of nutrients long-buried in the ancient soils of the Mississippi Embayment.

The Rise Of The Market Hunter And The Loss Of Wildlife

Between 1823 and 1832, the Federal government concluded a series of treaties with every tribe that had any claim to Missouri soil. Under the terms of these agreements, the pacified tribes were pushed into the Kansas and Oklahoma territories, land that whites still considered totally uninhabitable and unfit for civilization. For the next 50 years, this practice would become the norm when the government dealt with the resettlement of any Indian tribe. By 1832, all organized tribes had grudgingly moved from their lands in Missouri. A few straggling bands would continued to sneak into the state to hunt for the next several years, and some of these hunting trips resulted in isolated and minor incidents with settlers. For the most part, however, the state was now completely open to unchallenged white settlement.

With the loss of Indian hunters, the stream of wild provisions and goods would have to come from other sources. Until 1812, for instance, Shawnee living on the Bourbeuse River had supplied St. Louis with large quantities of meat. In the early 1820's, roughly 200,000 buffalo were killed annually along the upper Missouri River by Indian hunters who traded the hides and tongues, packed in salt, for shipment to St. Louis. Once they had surrendered their land claims, in 1825 and 1832, the delivery of meat to domestic markets was left to a growing breed of frontiersman, a very different breed, the white market hunter. These were men unlike any alive today. A market hunter shot, trapped, netted, poisoned, and clubbed anything furred, feathered, or finned that might bring a profit. As the population of Missouri continued to explode, white market hunters had to expand their operations far beyond what would have been required simply to fill the void left by the departing Indians. These hunters completely drained local wildlife populations as the burgeoning pioneer population doubled, redoubled, and doubled again.

Within a few years, hard-pressed hunters were forced farther and farther afield to satisfy the demands of a mushrooming St. Louis. In 1818 and 1819, a 10-month exploratory expedition camped on the

Missouri River near the Nebraska border was easily able to live off the land, taking between 2 and 3,000 deer and large numbers of turkey and bear. By the time Missouri became a state, a few short years later, hunters were having to travel as far as the White River region to find decent hunting. Furthermore, urban "sportsmen" killed many animals simply for the fun of it, and none of their parts were utilized in any justifiable manner. Bounties were instituted for wolves, bobcats, and mountain lions to protect both livestock and dwindling game populations. Despite such measures, game became increasingly scarce. In 1824, the chief of the Delaware living along the White River pleaded for assistance from the state because his hunters were unable to find game and his people were facing starvation. Even then, because of the numbers of white hunters, and excursions far to the west, city markets of 1825 were still able to supply venison, and grouse, duck, and turkey for 10 to 12 cents apiece.

As westward expansion continued, the situation deteriorated beyond belief. Opportunely situated as they were in the center of the main human migrational pathway - the Gateway to the West - the flora and fauna of Missouri reeled under the impact. The last Arkansas buffalo were butchered in 1837 and Missouri's held out no longer than five years after that. As game disappeared within the state's boundaries, market hunters ranged more widely and began to displace the plains tribes to the west. Until then, like the forest Indians before them, the plains Indian had also been supplying eastern commerce and industry with cheap natural products. The encroachment of these whites and the settlers that followed inevitably led to the great Indian wars that followed the Civil War. The pressure also led to the slaughter of Western game. Crucial to the butchery was a ready supply of willing participants and a convenient mode of transportation. The first was soon supplied in abundance.

By the 1830's, the rugged mountain man of the Rockies had already depleted stocks of beaver far below commercially productive levels. Combined with the opening of the China trade, a seemingly unrelated event, but one that replaced the fashionable beaver hat with one of silk, the bottom instantly dropped out of the fur market. By 1840, the price of beaver pelts had plunged 75 percent and the last of the great Rocky Mountain trading rendezvous had been held. For his livelihood, the voyageur and trapper was now forced to turn to the production of the increasingly fashionable buffalo robe. In no time, these highly experienced and incredibly able men would become the chief annihilators of Western game.

The Big Rivers

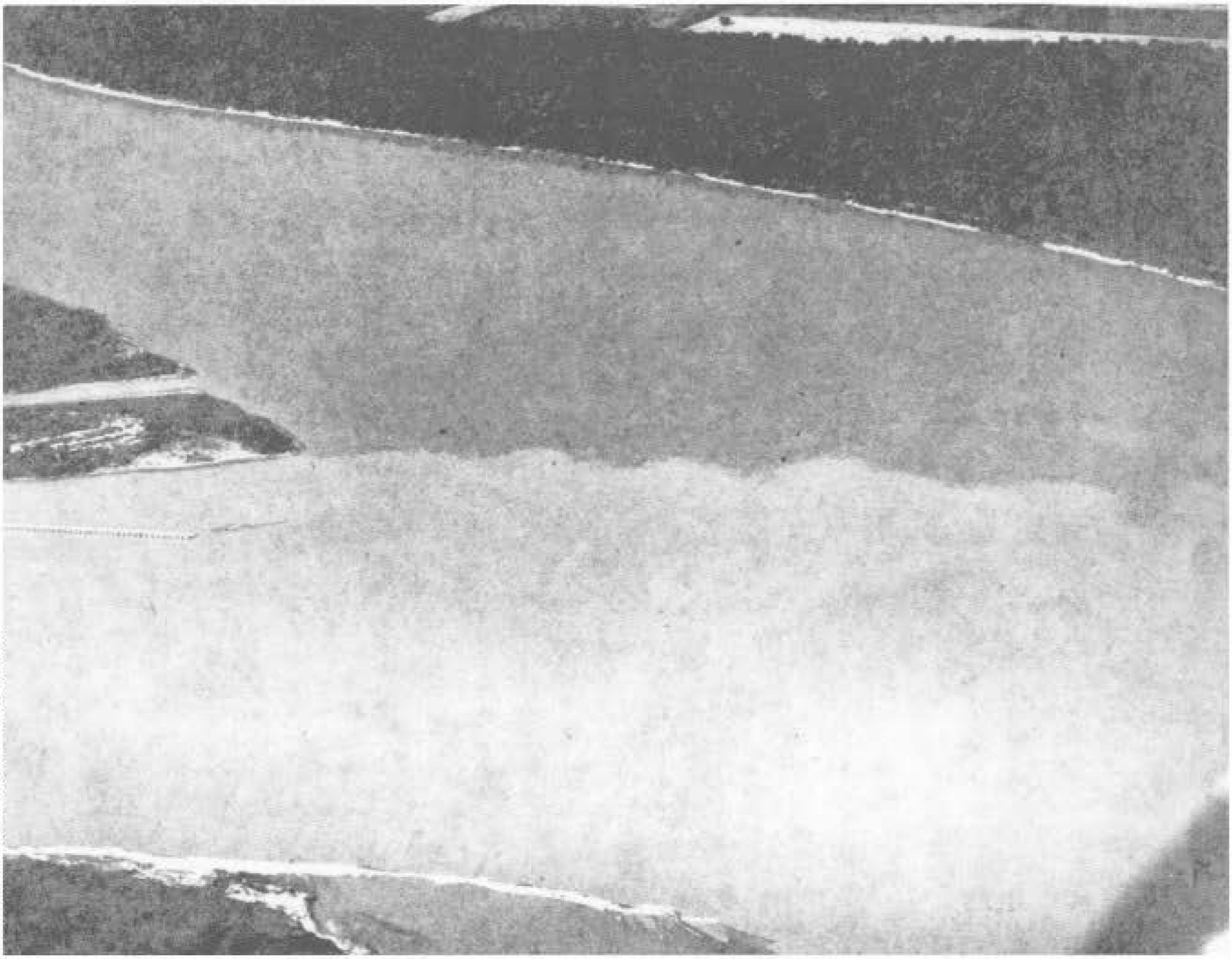
Until the railroads finally began to truss up and carve the Great Plains into easily digestible portions in 1860, traffic in buffalo and other western goods was restricted to riverboat and wagon. Overland travel from the plains to St. Louis was unbelievably slow and inefficient. Wagons often required a month or two for a one-way delivery. Since St. Louis had already become the major river port of the interior, via the Ohio and Mississippi rivers, it was only logical that, between 1820 and 1860, the system continue up the Missouri.

The Mississippi River drainage system ties together nearly a third of the continental United States. Benefiting from the contributed runoff of east, north, and west, the Mississippi has always been the most respected and admired American river. Native Americans, who had named it the "Great River," regarded the grand old stream with awe and reverence as they carefully plied its waters in birchbark and dugout canoes. Because it was as much as twice the length or breadth of any European river, and vastly larger than any other American river, early explorers, trappers, and settlers were also greatly impressed by the Mississippi.

While we tend to proudly view this network as one of the world's mightiest natural forces, we should be reminded that the mighty Mississippi, even when stretched taut for its entire 2,348 miles from Lake Itasca to New Orleans, is only the 17th longest river in the world, and that the oft-forgotten Missouri is actually longer than the Mississippi by 118 miles, and ranks 15th. Combining their forces (which American gazetteers always seem compelled to do) raises the Big River system into third place. To put things into perspective, the Amazon is navigable by ocean-going ships for 2,300 miles, all the way to the base of the Andes, a mere 48 miles short of the entire length of the Mississippi!

The Mississippi River, seen here from Riverview Park in Hannibal, is pooled for navigation through a series of 27 locks and dams from St. Louis to Minneapolis-St. Paul.

Jerry D. Vineyard



State Historical Society of Missouri, Columbia

Confluence of the Mississippi (upper) and the Missouri (lower) rivers shows the muddier Missouri mixing with the less-turbid Mississippi.

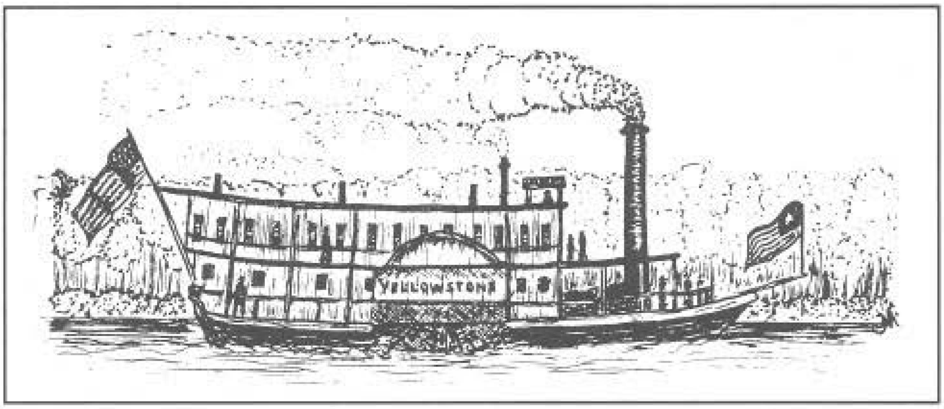
Though it is neither a Nile nor an Amazon, the creative and destructive forces of the Missouri-Mississippi river network are certainly the most potent in this neck of the woods. Although they are not the grandest in scale, America's big rivers nonetheless combine to produce one of the most important and famous drainage systems in the world. For thousands of years, this immense latticework has strung together the activities of human cultures, both historic and prehistoric. Beginning with the first dugouts, birchbark canoes, and hidebound bullboats, exploration, trade, and migration were all made possible by the vast network of streams that comprise the Mississippi-Missouri river chain.

The Missouri River was originally a prairie stream, shallow, choked with sand, and indecisive, like portions of the present-day Platte River in Nebraska or the Canadian River in Oklahoma. For thousands of years the river meandered widely within its broad flood plain, following numerous dividing, converging, redividing, and reconverging channels, all the while cutting liberally into its soft valley walls. Like other braided prairie streams, the Missouri was a nightmare for travelers.

Birchbark canoes of various sizes, and dugouts called **pirogues** were used by Indians, trappers, and early traders, but transporting families, livestock, and commercial goods required much larger vessels. For the first part of their trip, from Pittsburgh down the Ohio, then up the Mississippi, early settlers bought or built a flat-bottomed boat. These cumbersome barges could manage sizeable loads, but were always at the mercy of the current. Nonetheless, they were perfect for hauling the year's produce to market in New Orleans. A farmer and his neighbor might build and share a single craft, sell their goods and the boat after the one-month journey, then march home overland through Mississippi along the Natchez Trace, a trip of another three to four months. Needless to say, this was a dangerous, often fatal venture. Moving people and materials swiftly up or down a log-strewn, shifting channel required a much more maneuverable craft, sharp at both ends, and with a shallow keel. After 1780, keelboats from 40 to 80 feet in length, 7 to 10 feet across, and drawing about 2 feet of water when fully loaded became the chief means of ferrying passengers and freight on all rivers. Keelboats were either pushed along by crews with long poles, Mink Fink-style, or rowed, but rarely sailed on the Mississippi or Ohio. After 1800, really large keelboats of roughly the same length and shape, but twice as broad, were more commonly used for freight. Too heavy to be easily poled or rowed, these giant barges relied more often on the wind.

The first steamboat to make the journey from Pittsburgh to New Orleans left in September of 1811, but was delayed by shallow water and the now-famous earthquake in the New Madrid region. Robert Fulton's craft, the New Orleans, finally arrived in January 1812. It continued to ply the Mississippi for three more years until, like so many of its kind, it hit a snag and sank. The first to navigate Mississippi waters upstream from the Ohio, the Zebulon M. Pike, reached St. Louis on August 2, 1817. The Missouri River was generally shallow enough to permit the use of poles to push these angular-bottomed boats upstream, but finding a single main channel in which to travel was a real challenge. The current dragged so much sediment from its barren upstream reaches that the channel could literally change from day to day. On the other hand, except when in flood,

The Yellowstone was the first steamboat to navigate the Missouri into Montana.



the Missouri was a rather lethargic stream and sails were often sufficient to drive boats upstream if there was a fair wind. Still, sandbars and snags clogged the constantly shifting channel for much of the year, greatly hampering navigation and making legends of rivermen who managed to arrive intact and on time.

Most of the year, river commerce depended on small keelboats or flat-bottomed craft, because there was simply not enough water nor a clear enough channel for the larger steamboats. While enormously heavy traffic plied the Mississippi - an estimated 3.32 billion freight-ton miles and 1.1 billion passenger miles in 1849 alone! - the unpredictable Missouri claimed over 100 steamboats in the 30 years before the Civil War. Any Missouri riverboat captain who could actually deliver became an instant hero. As much as they plagued pioneers, the numerous islands, snags, backwaters, and sloughs greatly enriched the river for breeding and migration of fish and waterfowl. For the first century or two, hunting and fishing along the Missouri were both highly productive and widely acclaimed.

The bulk of the Missouri's yearly flow originally came during two peak periods. The first was early in the spring when the high plains thawed, disgorging a torrent of muddy water from the Dakotas, Montana, and Wyoming. The second major gush swept downstream with the melt of deep snowpack in the Rockies, joined by heavy runoff from spring rains out on the prairie. In addition to these seasonal fluctuations, the flow could also vary greatly from year to year. During a particularly harsh winter, for instance, when much of its water was tied up as snow and ice, the Missouri might be reduced to a mere trickle, with a flow as low as 4,200 cubic feet per second. That is roughly equivalent to the Meramec in flood at Steelville or approximately three times the average flow of the Current River near Round Spring, but spread across a quarter-mile of channels. With the thaw, the instantly swollen river might carry as much as 670,000 cubic feet per second, a frightening difference if one were planning an early spring departure for a western hunt.

The once-wild Missouri River, now tamed by upstream dams and downstream dikes, serves as a watery highway of commerce. Here, a barge tow pushes upstream against the current. High bluffs near Rocheport flank the eastern valley wall; a small section of the Katy Trail is visible in the right center of the photo.

Jerry D. Vineyard

Since the turn of the century, six major reservoirs in Nebraska, the Dakotas, and Montana have mostly eliminated the seasonal peaks. At the same time, they have evened out the annual rates of flow and lowered the Missouri's silt content by more than half. Channelization and navigation projects that began with the creation of the Missouri River Commission in 1884, have continued to the present day with the activities of the Army Corps of Engineers, converting the once independent river into a highway of water-borne commerce.

The Bank Stabilization and Navigation Project, completed in 1980 at a cost of $427 million, virtually eliminated all of the river's islands, bars, meanders, braided sections, backwaters, and sloughs, destroying habitats that supported the abundant wildlife reported by Lewis and Clark. Typical Missouri River fish, such as the silvery minnows, pallid sturgeon, and flathead chub, may be in danger of disappearing from the lower sections of the Missouri as direct or indirect results of the decline in silt. Some fed in silty backwaters that have all but vanished; others must now compete with growing populations of fish characteristic of the Missouri's less turbid tributaries, such as the Ozark minnow, longear sunfish, and spotted bass, which have actually increased since channelization.

Most wildlife changes are due to physical changes in the river itself. Indeed, the Missouri is actually 8 percent shorter today because of straightening and has lost about half of its total water surface area due to constriction of the channel. Over 60,000 acres of prime wildlife habitat, including 24,000 acres of islands along 550 miles of the river's course were lost in Missouri alone during the construction phase. An unrecognizably docile version of its former self today, the wild Missouri River of the voyageurs, Lewis and Clark, and the keelboat pilots was a stream to be reckoned with.

In contrast, relative to the wild and unpredictable Missouri, the original Mississippi River traveled a path of moderation. Because the upper Mississippi River watershed is largely forested and receives reliable amounts of precipitation nearly every month of the year, spring flooding was always less severe than along the Big Muddy. In addition, the Mississippi's heavily vegetated drainage basin metered snowmelt and runoff throughout the entire year, rather than in two tumultuous bursts. The result was a reasonably calm river, one that, although extremely challenging for riverboat captains, was a piece of cake when compared to the cantankerous Missouri.

Above its confluence with the Missouri, the Mississippi had always been a fairly clean, pretty river. With its vegetation-cloaked banks and hillsides, little silt escaped the land to mar its blue waters. If the Missouri was not in flood, the water was clear even as far downstream as New Madrid. Following the construction of a long string of navigation locks and dams early in this century, it lost even more of its already low turbidity as the small amounts of silt and fine sand settled out behind dams. At one time, the Upper Mississippi more closely resembled a huge Ozark border stream, with long, deep pools separated by riffle-like rapids and sandbars. Today, rapids exist mainly in the short reaches of channel immediately below each dam. Silt now buries the old sand and gravel floors of the pools, and is swept away for only a short distance downstream by discharge and overflow from the dams. Most swiftwater breeding sites for important commercial fish, like sturgeon and paddlefish, were destroyed by this chain of locks and dams. On the other hand, the spreading backwaters of navigation pools have encouraged waterfowl and stillwater fish.

Once the Missouri and Mississippi rivers join they produce a much larger river that should, one might think, possess characteristics intermediate between the two; however, this next stretch of the Mississippi, called the Lower Mississippi, is actually more like the Missouri in appearance and nature, so overwhelming are the silt load and flooding cycles of that tributary. For the next 150 miles, the big river is hemmed into the deeply entrenched Pleistocene channel of its own making, and now sweeps alternately from the Missouri to the Illinois bluffs and back. Once the Father of Waters leaves its sheltering walls of limestone and dolomite south of Cape Girardeau, it takes on an entirely different aspect. Part of the change in demeanor is due to a rapid increase in size as the Mississippi receives the greater volume of the Ohio River from the east.

Although it is a much shorter river and drains only a third of the area that feeds the Mississippi to that point, the Ohio contributes 58 percent of the total flow of the Lower Mississippi River. The Ohio watershed picks up a tremendous amount of rainfall each year along the western slopes of the Appalachian chain. Gurgling and tumbling down the rocky, heavily vegetated slopes of those mountains, the relatively clear water of the Ohio helps dilute the Mississippi's turbidity. The Ohio's immense volume is able to lower the muddy influence of the Missouri River by roughly one-fifth. As a result of their more reliable rates of flow and their larger size and deeper channels, the Ohio and Lower Mississippi were always more important channels of commerce and travel than the crazy Missouri. Even so, they were never safe, not by anybody's definition, and more than 1,000 steamboats were claimed by these big rivers in the days of Mark Twain.

Prior to the coming of the railroads, the Big Rivers were the main route by which immigrants arrived in Missouri and the principal means by which the state's resources were shipped out. In the mid-1800's steamboats transported in one year as much as all the railroads of the United States carried in a single year one decade later. The Missouri-Missisippi-Ohio network was fundamental to westward movement and the development of the Louisiana Territories. Situated near the confluences of these rivers, St. Louis became a center of commerce and a staging area for westward expansion.

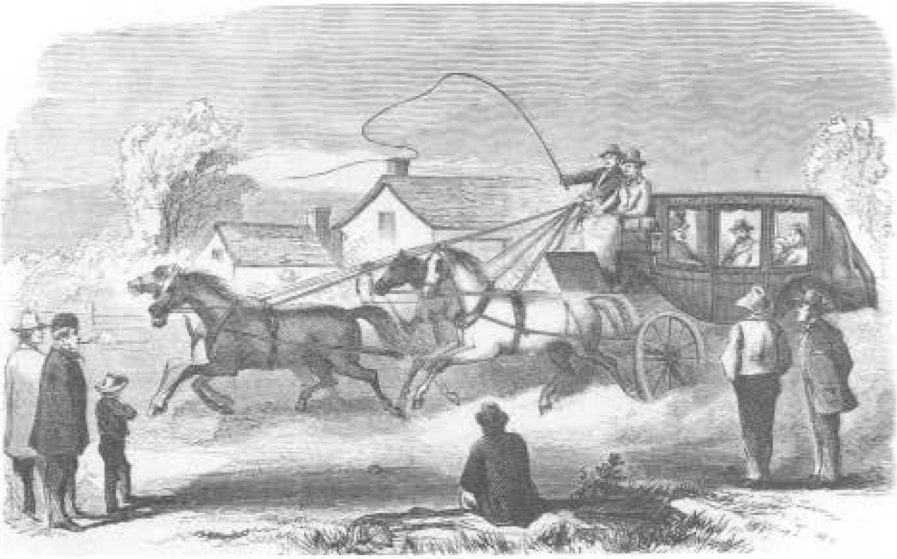
The Coming Of The Railroads

The 1840's brought tumultuous changes to the world and to the United States. Within the three years of 1845-1848, the Irish potato famine struck and revolutions toppled continental monarchies, driving millions of immigrants to the United States. In a heavy-handed series of events justified by Manifest Destiny, an ideology of the time which held that Americans had a moral obligation to expand westward, the United States annexed Texas from Mexico and, as a consequence, entered into and won a war with that country. The spoils of that war yielded an additional one million square miles of territory, including much of Colorado and New Mexico, and all of Arizona, Utah, Nevada, and California. The nation also settled a dispute with Great Britain over the location of the Canadian-Oregon boundary.

By 1850, the land area of the United States had increased by approximately 50 percent. In 1840 the non-Indian population of the United States was reckoned to be just above 17 million, spread throughout the settled part of the nation at roughly two people per square mile. At the time less than half the 1.8 million square miles of American territory was inhabited by whites and blacks; approximately half was unsettled. By the end of the decade, with annexations, conquests, purchases, compromises, and an additional 300,000 immigrants per year flooding eastern ports, these statistics became meaningless. Gold was discovered in California in 1849, spurring westward expansion beyond anyone's wildest dreams. The demand for freedom, free land, and wealth drove settlers west. By 1860, 4.3 million Americans had moved west of the Mississippi and St. Louis had become the seventh largest city in the United States. The Mormon, Oregon, California, and Santa Fe trails carried a flood of pioneers westward. All this was in an era of travel through canals or along rivers by flat-bottomed boat, keelboat, and steamboat, or over rutted trails by horse, overland wagon, and foot. Much of the westward gold rush traffic was by sea, either through the Straits of Magellan, or across the fever-infested Isthmus of Panama.

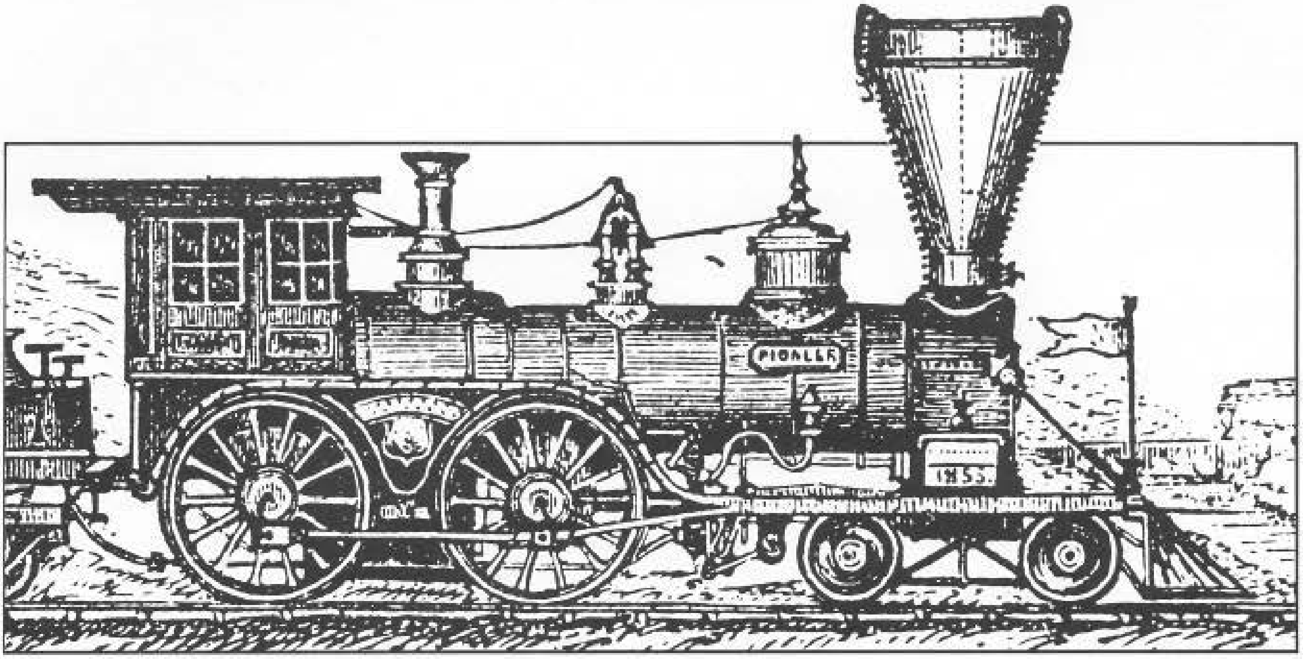
As a result of the huge distances and the rigors of travel, Westerners, especially Californians, felt isolated and demanded a greater level of attention from their distant eastern capitol. Great Plains and western freight traffic was quite heavy, even though government involvement was negligible. From Lexington, in Lafayette County, one firm alone developed a huge trading network that, by 1858, employed 4,000 men to manage 3,500 wagons pulled by 40,000 oxen. In 1850 the federal government contracted with an Independence firm to begin monthly delivery of mail by wagon as far as Santa Fe. Finally, to quell growing Californian demands, the government negotiated a contract in 1858 with two gentlemen - John Butterfield and William Fargo - to establish an overland mail route to California. These two set up the Butterfield Overland Express and soon expanded their freight and postal service to include passengers. The line became the model for our familiar Hollywood "Stagecoach" image of the West. Despite the loads they carried and their romantic image, such wagon lines were not up to solving the problem of westward expansion; railroads provided the solution.

The stagecoach, faded in folklore of the old west, was not up to solving the problems of westward expansion; railroads were.



The State Historical Society of Missouri, Columbia

In 1840, there were only 3,000 miles of railroad track in the entire United States, most of it in the industrial northeast. Westward expansion forced the growth of the railroad, the cheapest and most reliable means of moving goods and people long distances cross-country. In 1845 overland wagon freight rates were 40 to 100 times as high as river rates; railroads cut overland rates to one-eighth the wagon rate, and delivered more quickly and more reliably. The mileage of


The State Historical Society of Missouri, Columbia

The "Iron Horse" revolutionized travel and freight shipment in Missouri, beginning in the mid-1800s.

rails doubled by the end of the decade and reached 30,000 by 1860, firmly linking the old Northwest Territories with the East Coast. In 1850 there was not a single mile of railroad track in the Chicago area. Within five years, 2,200 miles of track had been laid that served 150,000 square miles centered on the growing city. The railway links between the Great Lakes and the industrial northeast would prove highly providential to Chicago and would contribute ultimately to the commercial and industrial retardation of St. Louis. By the 1870's, the Windy City would become the railroad center of the nation and the epicenter of transcontinental trade.

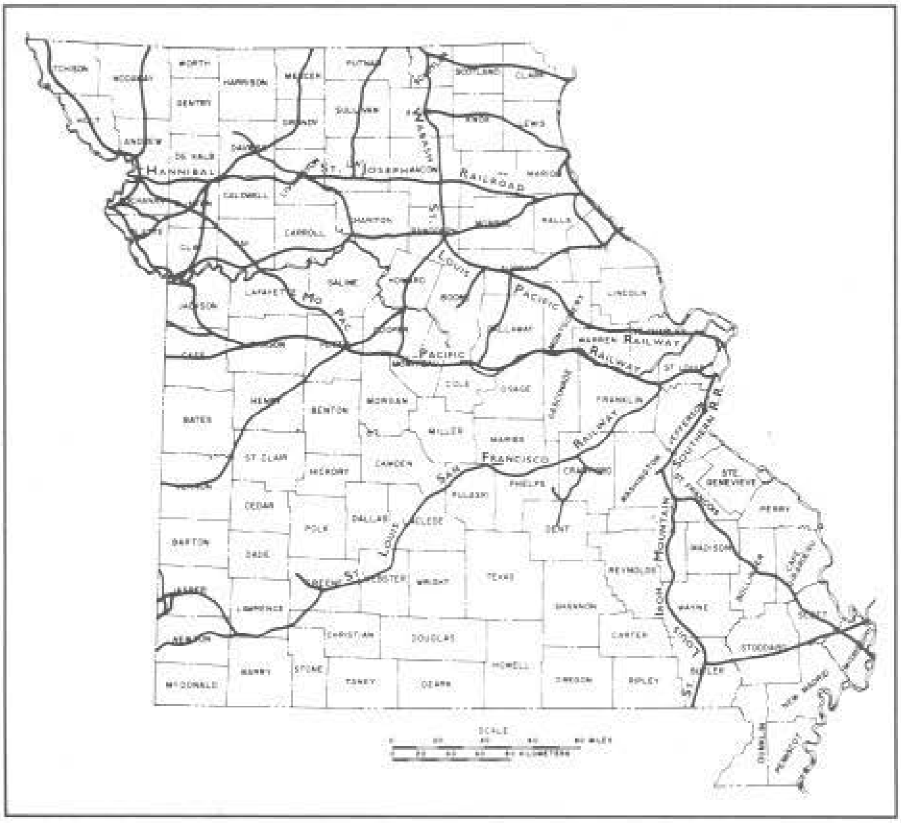
Not that Missouri was disinterested in railroads. Two railroads had been proposed as early as 1836 to link St. Louis with Fayette, in Howard County, and with the mining districts to the southwest, but financial difficulties forced planners to scrub the plans. The first Missouri railroad, built between 1849 and 1851, could scarcely be called a railroad by today's standards. Drawn by mule over rails of white oak and walnut, the primitive track connected the Missouri River with Farmville, a small town no longer on any map, but originally a bit north of Henrietta, in Ray County.

After 1851, interest in building railroads in Missouri intensified. Over the next decade 104 charters were granted, but only seven companies received financial aid from the state and actually laid significant amounts of track. Of these, the most important were the North Missouri, to run from St. Charles up the Missouri-Mississippi divide through Macon to the northern border; the St. Louis and Iron Mountain, to connect St. Louis with the mines at Pilot Knob; the Pacific, to cross the state along the Missouri River Corridor from St. Louis, through Jefferson City, and on to Kansas City; the Southwest Branch of the Pacific (known later as the Southwest Pacific Railroad, then the South Pacific, finally the St. Louis and San Francisco), to head from Pacific to the southwest boundary of the state; and the Hannibal and St. Joseph.

Construction was slow. In 1855, a commission was established to study how the state's money was being spent and found that only 100 miles of track had actually been laid. Strangely, they noted no evidence of graft or corruption; "strangely," because railroad construction was the shady center of unscrupulous activities nationwide and the chief means by which a devious entrepreneur could get rich quick. In any event, because of favorable financing from East Coast interests and generous land grants, the Hannibal and St. Joseph was the first line to cross the state, in 1859. The Pacific Railroad reached Kansas City in 1865 and the North Missouri completed its track some time after the Civil War.

Railroads brought development and prosperity to the areas they served and nearly everyone became railroad-minded during this 40 year period. Towns and cities competed sharply, sometimes violently for a route. A town with a railroad thrived; one without shriveled and often died. For those near a line property values and commercial profits soared. Because commerce and settlement were in the national interest, state and federal government grants and subsidies were to be had in abundance. As an additional incentive, over 130 million acres of unoccupied land were deeded to railroad financiers. Companies involved in laying the first transcontinental lines, for example, were granted 20 sections of land on either side of the track for each mile laid. When the line was completed such land often became extremely valuable and builders could name their price. Railroad builders and backers generally became extremely wealthy. Tremendous spurts of track-laying in the 1860's and 70's crisscrossed Missouri's prairie regions and the Bootheel; with few exceptions, the railroads avoided the rugged Ozarks.

Railroads of Missouri in 1878



HANNIBAL
ST. JOSEPH
RAILROAD
WABASH
ST. LOUIS
PACIFIC
MO PAC
PACIFIC
WARREN RAILWAY
RAILWAY
ST. LOUIS
SAN FRANCISCO
RAILWAY
ST. LOUIS
IRON MOUNTAIN
SOUTHERN R.R.
ST. LOUIS
ATCHISON
NODAWAY
WORTH
HARRISON
MERCER
PUTNAM
SCHUYLER
SCOTLAND
CLARK
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SULLIVAN
ADAIR
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MARION
CALDWELL
CARROLL
CHARITON
RANDOLPH
MONROE
RALLS
CLAY
LAFAYETTE
SALINE
HOWARD
BOONE
LINCOLN
JACKSON
COOPER
CALLAWAY
WARREN
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JOHNSON
PETTIS
MONITEAU
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OSAGE
GASCONADE
FRANKLIN
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MORGAN
MILLER
MARIES
JEFFERSON
ST. CLAIR
HICKORY
CAMDEN
CRAWFORD
WASHINGTON
STE. GENEVIEVE
VERNON
CEDAR
POLK
DALLAS
LACLEDE
PULASKI
PHELPS
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ST. FRANCOIS
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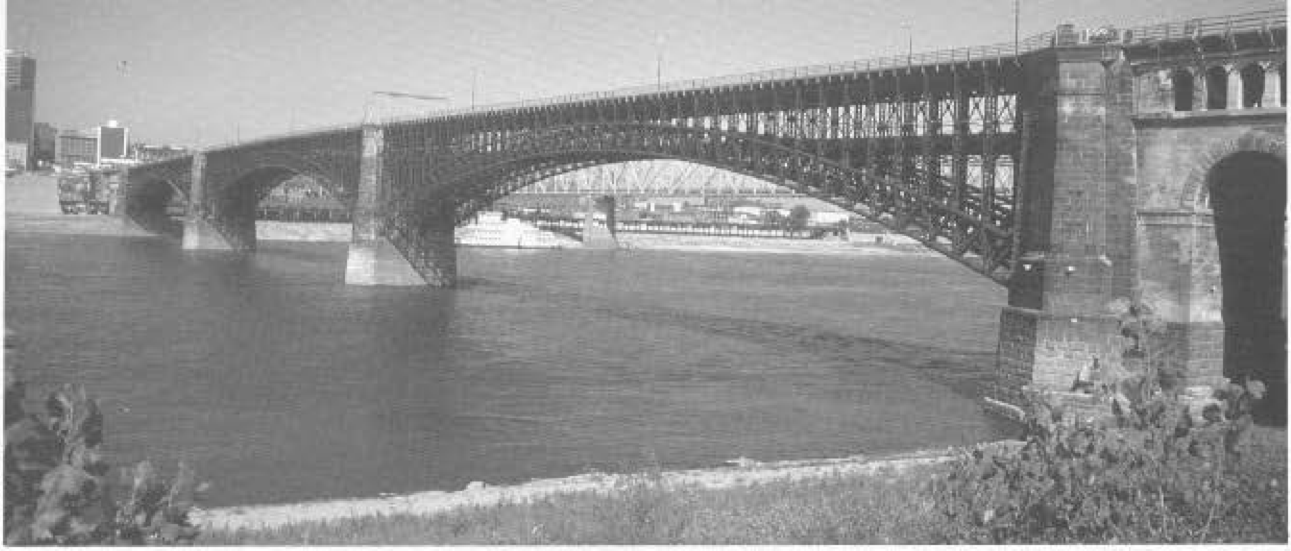
BARTON
DADE
MADISON
CAPE GIRARDEAU
JASPER
GREENE
WEBSTER
WRIGHT
TEXAS
REYNOLDS
BOLLINGER
LAWRENCE
SHANNON
WAYNE
SCOTT
NEWTON
CHRISTIAN
DOUGLAS
CARTER
STODDARD
MISSISSIPPI
McDONALD
BARRY
STONE
TANEY
OZARK
HOWELL
OREGON
RIPLEY
BUTLER
NEW MADRID
DUNKLIN
PEMISCOT
SCALE
MILES
KILOMETERS

Local Aid to Railroads in Missouri by Edwin L. Lopata, 1909

Despite the mushrooming of Missouri railways, the expanding system could not prevent the stealing of St. Louis financial, commercial, and industrial thunder by a better-situated and more


Jon Hawker

Eads Bridge, designed by John Eads and completed in 1874, gave Missouri railroad lines access through St. Louis to the rest of the country. An engineering marvel for its time, the Eads Bridge is being readied to carry light rail as part of the St. Louis metro area's mass transit plan.

venturesome Chicago. Railroads were much easier to build to the north. Iowa was settled and achieved statehood some time after Missouri and still offered considerable free land for granting to railroads as they came along. From an engineering standpoint, the more recently glaciated topography and geology of northern Illinois and Iowa were as conducive to laying lines as they were to farming. It was inevitable that Chicago became the center of trade in agricultural products.

Ironically, the completion of the Hannibal and St. Joseph railway helped in the eclipsing of St. Louis. Missouri River freight traffic could leave the river in St. Joseph and, once transferred to the Burlington line, head straight across the nation through Chicago, avoiding miles of slow Missouri River meanders, ice, and sand, and the equally unreliable and treacherous Mississippi. This northerly overland route was made possible by completion of the Rock Island Railroad's bridge at Davenport, Iowa, completed after 1855, and was strengthened by the Burlington's own bridge at Quincy, Illinois, in 1868. The northerly locations of these trans-Mississippi bridges forced southern Missouri railways northward into Iowa or northern Illinois, away from St. Louis, if they were to join the growing American railway network.

Only after the iron bridge designed by James Eads was completed in 1874 did Missouri lines have direct access through St. Louis to the rest of the continent. Unfortunately the bridge came more than a decade too late to prevent Chicago's supremacy. Northern farmers could ship directly through Chicago to eastern markets via rail, or via ships across the Great Lakes. A further blow to St. Louis's bid for long-term domination of commerce came after the Civil War when the transcontinental railroad bypassed Missouri altogether. Essentially following the Oregon Trail along the Missouri River through Nebraska, the northerly route of the Union Pacific offered the shortest, easiest route to the mountains. Eastern investors recognized the benefits of connecting to the existing lines in the Chicago area via the Rock Island Railroad. Unfortunately, the linking of the continent through Nebraska and the Rocky Mountains was not the last insult to be borne by St. Louis.

To the west, Kansas City businessmen began establishing trade in western beef. When the Pacific Railroad refused to do business with the fledgling cattlemen, the stockmen decided to bypass St. Louis and deal directly with Chicago. To be successful, these Kansas City entrepreneurs had to outdistance their close rivals in St. Joseph, who were also vying for the trade in western beef. Consequently, a group of determined Kansas City businessmen built the first upstream bridge across the Missouri River. Through the Kansas Pacific Railroad to the southwest and the Burlington to the northeast, they established the link between Chicago markets and the growing cattle supply of Abilene, Kansas, and the southern plains. Chicago meat-packing firms quickly opened branches in Kansas City and St. Louis was once again out-flanked. St. Louis only regained status on northeastward trade routes after completion of the Missouri Pacific and the St. Louis and San Francisco (Frisco) railroads.

Following the Civil War, Chicago became the new focal point of westward expansion and the eastward funnel for western farm products. By 1878, Chicago was receiving over three times as much grain, more than twice as many cattle, four times as many hogs, five times as much butter, and six times as much lumber as St. Louis. As settlers flooded the West and cattle replaced buffalo, the Kansas meat-packing industry mushroomed. St. Louis, deprived of these valuable commodities, remained the center of the much-reduced trade in western furs and the meteoric rise and fall of buffalo products. As a result of railroad positioning, Chicago got rich on the grain of the northern plains, Kansas City became famous for its stockyards and beef, and St. Louis wound up with the Fouke Fur Company. Inter-city rivalries obviously predate professional sports by nearly a century. Railroads hastened the development of the nation's heartland and its conversion to the "breadbasket of the world," the Corn Belt. In doing so, the vast native grasslands of northern Missouri and the plains to the north and west were plowed and covered by agricultural grasses, principally corn.

Oddly, despite their accelerating influence on the development of farmland, without these early railroads we might not have any original grassland in northern Missouri at all. The first railroads sometimes preserved bits of the original prairie in their unplowed rights-of-way, such as in Montgomery County along the original North Missouri Railroad line (then Wabash and more recently Norfolk and Western) between Montgomery City and Martinsburg.

The Great Western Extermination

The advent of the iron horse in the 1850's and 60's eliminated the risk of shipping by water and most of the inefficiencies of overland travel. Railroads quickly allowed game shipments to reach immense proportions, numbers that are absolutely incredible by today's standards. Between one and two million buffalo were killed each year between 1872 and 1875. The bloody butchery drained the grasslands of animals so quickly that, by 1885, no huntable buffalo could be found on the northern plains. The motives behind the hunting were several. There was the continuing need for large supplies of cheap meat. Buffalo robes became a new fashion craze. Other herds were wiped out simply to curtail railroad and telegraph damage. And, to help eliminate the Indian threat following the Civil War, William Tecumsah Sherman, late of "March Through Georgia" fame, transposed his winning strategy into Indian Territory, intent on depriving the heathen of his primary means of support. The prairies were littered with buffalo remains. A whole industry grew up around the skeletons alone. A number of St. Louis firms made huge fortunes processing millions of tons of bones into meal for fertilizer and carbon for sugar refining.

During this same period, the lure and lore of the grand western hunt attracted multitudes of sportsmen to the carnage. They were encouraged by the railroads, who wanted to sell tickets, stimulate development of the West, and eliminate the train-stalling, track-ripping, and telegraph-snapping herds from along their rights-of-way. Bizarre hunting caravans left from both St. Louis and Kansas City. Hundreds paid to ride to a western outing in style and comfort. Some St. Louis parties were led by that notable frontiersman, hunter, and showman, William F. "Buffalo Bill" Cody. A string of passenger, smoking, dining, and freight cars behind the locomotives allowed pampered hunters to blast at animals through open windows. Contests were held just to see who could shoot the most buffalo in a single day. One such contest was waged to determine the all-time champion buffalo hunter of the plains. The result: 46 for the loser, Billy

Nick Decker

Buffalo, as well as elk, bear, mountain lion, and wolf would be completely wiped out in Missouri and most eastern states. These buffalo, photographed in Prairie State Park, populate a small part of Missouri's original prairie, never plowed.

Comstock; 69 for the winner, the intrepid Buffalo Bill. Tons of heads, hides, meat, and tongues were hauled back, but much was simply left to rot. Of course, buffalo were not the only victims. Elk, bear, wolves, prairie chickens and other game suffered similar punishment. Nor were prairies the only communities threatened. Similar excursions were conducted throughout Missouri and into Arkansas.

For over 75 years, every kind of wild animal population, whether furred, feathered, or finned, would experience a continued, undiminished and thorough ravaging by market and sport hunters. At the end of this period, the passenger pigeon, hauled to St. Louis markets by the wagonload in 1859, and the Carolina parakeet would both be extinct. The buffalo, elk, bear, mountain lion, and wolf would be completely wiped out in Missouri and most eastern states. Populations of deer, beaver, turkey, quail, otter, bobcat, fox, ruffed grouse, prairie chicken, ducks and geese of all kinds, snipe, woodcocks, egrets, doves, all edible fish, and many songbirds would reach levels that by today's standards would have seemed unimaginably low. Even with the unyielding pressure of market and sports hunting, not all wildlife populations should have suffered so terribly. Unfortunately, during the relentless development of the 19th century, market hunters had not been acting alone.

Because rapid transportation, refrigeration, and a stable meat supply were generally nonexistent in the 1800's, the growing urban population relied heavily on native fish and wild game for food. Furs, hides, and feathers were widely used for clothing, shoes and hats. The market hunter made his living supplying these demands. Day after day, year in and year out, the market hunter trapped, shot, and netted animals in the quickest, most efficient manner possible, without regard to numbers, age, sex, or season. The new transcontinental railroads sped the shipment of meat, hides, furs, feathers, skins, and bones from dwindling western populations to Missouri and Eastern markets.

Declining Wildlife And The Introduction Of "Weeds"

As obvious as many wildlife issues may seem to us today, at the time there was little comprehension of the basic needs for food, water, and shelter. Few realized that the century-long destruction of habitat, coupled with the more obvious target of market hunting, was really the root cause of the sad decline and demise of Missouri's rich resource heritage. The loss of game animals encouraged sportsmen's organizations, overzealous politicians, and ordinary citizens eager for the quick fix, to import many species to augment disappearing stocks. At the time there were no laws governing the importation of foreign species and even the federal government became a major player in the importation business. The list of imported animals included not only those with potential game value, but also a large number valued for their beauty and song.

Among these were "songbirds" such as the starling and house sparrow, intended to cheer folks who had just come over from the old country, to spruce up America's cities, and to replace native species whose numbers had seriously declined. One fellow wanted to import all the species mentioned by Shakespeare. The list of non-native animals intentionally introduced into Missouri, referred to usually as "exotics," included white shad, rainbow, speckled and brook trout, tench, carp, and California and landlocked salmon; starlings, house sparrows, tree sparrows, chaffinches, bulfinches, greenfinches, goldfinches, and siskins; California, Texas, and Coturnix or migratory quail, bamboo and European partridge, and ring-necked pheasant; and elk, fallow and red deer, and angora goats. Not ideally suited to the new habitats into which they were introduced, the majority of this incredible barrage of foreign species luckily vanished. Of those that were able to survive and establish themselves, most were destined to become pests. Some brought in parasites and diseases with them when they came. Others, like the starling, sparrow, and carp, competed openly with native species already sorely tested.

Only a very few exotic species, such as rainbow trout and ring-necked pheasant, have ever proven successful in a wild context, or could be thought of as even marginally beneficial. The trout displaced only native species with little or no economic value, while the pheasant filled a niche in Missouri's disturbed grasslands that in their undisturbed state would have been occupied by the prairie chicken. Other introduced species, such as muskellunge, provide valuable sport in artificial impoundments and do not seem to have become part of the "natural landscape." Many of Eurasia's, Africa's, and South America's most common pesky animals became part of the Missouri landscape simply by accident. Our houses, barns, backyards, and greenhouses now harbor seven different kinds of European slugs, European house and long-bodied spiders, house and greenhouse centipedes, greenhouse millipedes, European pillbugs and sowbugs, several cockroaches, crickets, earwigs, aphids, mealybugs, whiteflies, borers, bugs, beetles, and butterflies. The infamous black and Norway rats and house mouse round out the list.

A similar scenario was repeated with plant materials. Enormous numbers of exotics arrived accidentally with each shipment of immigrant humans and their livestock, but North America was also aggressively "tamed" with Eurasian vegetation of all sorts. With few

Honeysuckle, a European plant that found Missouri's climate and soils to its liking, crowds out native plants in some areas.

Susan Dunn

exceptions, our farms, yards, cities, and parks all became "little Europes," beautified by exotics. Many of these plants have "escaped" cultivation and have established wild populations. Trees such as Ailanthus, or Tree-of-Heaven, shrubs like Amur honeysuckle, common privet, and multiflora rose; vines like Japanese honeysuckle and kudzu; and herbs like fescue and crown vetch sometimes seem about to choke us all. Every lawn is a lesson in European botany. In the St. Louis area, the Amur honeysuckle is on the verge of eliminating all understory vegetation in the forests where it has become established, which is nearly every patch of woods in the county. In wetlands throughout the country, the European loosestrife has choked out native plants to such an extent that it has been declared a noxious weed in Missouri, albeit *ex post facto.* The simultaneous introduction of plant pests and diseases with this range of stock has killed the American elms that lined our streets and shaded our midwestern towns, and wiped out our eastern chestnut forests.

Susan Dunn

A major nuisance in the South, Kudzu tends to cover everything within reach, such as this blanket along old Highway 66 in Pulaski County.

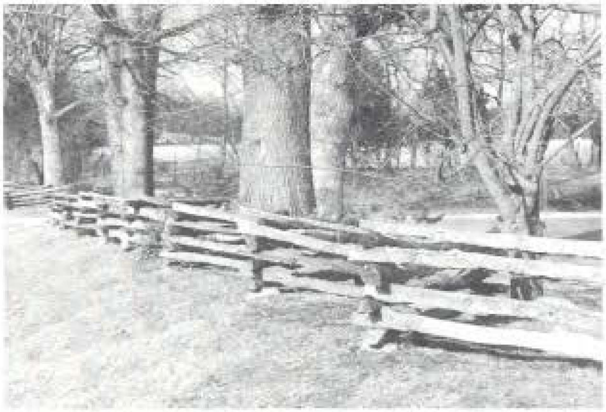
Actually, the trans-Atlantic movement of plants and animals has been a rather open exchange. American diseases of grapes wiped out European vineyards until prized varieties were grafted onto American rootstocks. Today, the English gardener proudly shows off his prize collection of goldenrods to visiting Americans who roll their eyes in amazement and try to look impressed. His neighbor, a forester, fusses over damage done to trees by eastern gray squirrels, while across the channel in the Netherlands, pest control experts battle the burrowing muskrat as a matter of life or death.

Experimentation with exotics continues around the world, long after everyone should be familiar with the potentially dangerous consequences of such foolhardy action. Luckily, the major thrust of uncontrolled wildlife introduction efforts died with the adoption of more scientific programs in the 1930's. Today most governments are extremely careful about introductions into their countries.

The Golden Age Of Wood Products

Until the early part of the 20th century, much of Missouri was deep in what has been called the "Wooden Age." During the approximately 100 years from statehood until the development of oil, coal, and rural electrification there was an extremely heavy demand for cordwood and, until metals, concrete, and asphalt came to the fore, lumber for buildings, boats, wagons, and furniture; rails for fences; planks for roadways and sidewalks; and slats, panels, and ribs for containers and packaging of all kinds. Only gradually did "modern" materials replace wood as the chief substance of technology and society. Wood provided the materials for wind and water wheels used in all milling operations, including the gears, axles, rods and other connections. Tools were often made entirely of wood. The forest was the source of pitch, tar, turpentine, wood alcohol, potash, dyes, and tannins for leather production. With the passing of each decade before 1890, the exploding population of Missouri - the center of settlement farther to the west - more than doubled its wood needs: more than doubled its buildings, its furniture, its firewood consumption, its fencing, and its chemical processing; more than doubled everything every decade for nearly a century. The ongoing lead smelters and newly developed ironworks and foundries at Iron Mountain, Pilot Knob, and Maramec Spring consumed vast acreages of firewood, both to fire the furnaces and to produce the charcoal necessary for carbon steel production. The advent of the steam engine increased the pressure on the nation's forests. With the arrival of the first steamboat in St. Louis in 1817, an event that became commonplace by 1819, and the first railroad in the 1850's, the demand for firewood increased dramatically.

Rail fences, a nostalgic part of Ozark landscapes, once consumed large numbers of trees and required back-breaking labor to build; they are rarely seen today.



Susan Dunn

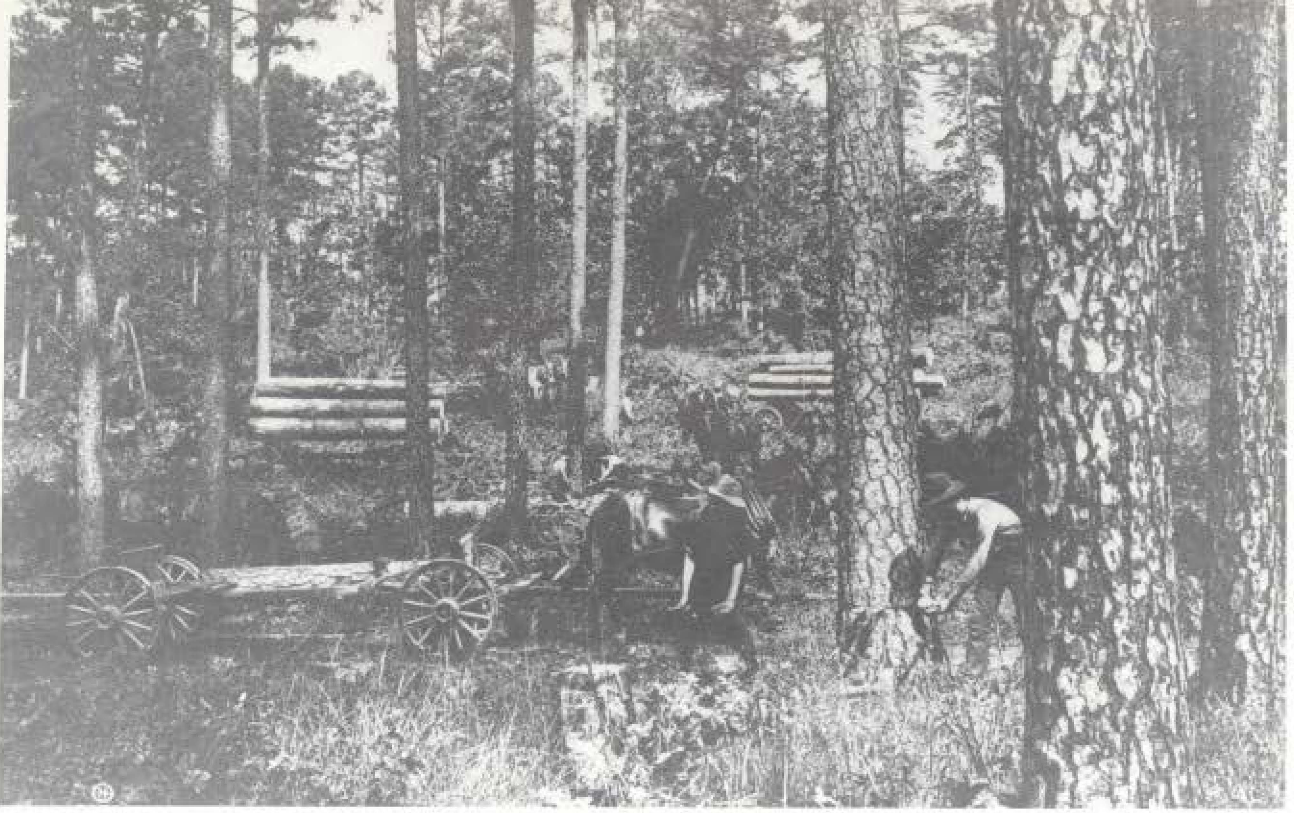
Prior to the development of coal, steamboats had to tie up along the banks at regular intervals so that crews could lay in enough wood to continue the tedious upstream journey. Trains were faced with similarly frequent refueling stops. Even worse, a single mile of track required 3,000 ties - each 8 feet long, 6 inches thick, and 8 inches wide - and, in the period before pressure-treating with preservatives, every one had to be replaced at the end of a seven to 10-year period because of rot. Hundreds of miles of Missouri tracks and many eastern sections of the transcontinental railways were laid on timbers cut from the Ozarks. The central part of the nation seemed to be tied together with Missouri oak, hickory, sycamore, walnut, and sassafras, the most popular woods for tie production.

Along the Niangua and Osage rivers in the 1870's, for instance, crews of 300 to 500 men cut between 40 to 50 ties per man, each and every working day. The spreading network of railroads over the next 50 years helped lead to the loss of 75 percent of Missouri's forested lands. Of course, only a small part of the loss could be directly attributed to the needs of the railroads themselves. The role played by the railroads in opening new regions to development, generating population growth, and transporting goods to market was far more important to the increased pressure on timber resources than the small amount of wood products required to actually operate the steam engines and maintain the rails.

In the centuries before preservatives, rotting wood affected everyone, not just the builders and owners of railroads. Beams, timbers, and planking had to be replaced frequently as fungi, ants, and termites took their inevitable toll. New rails to shore up badly weathered fencing had to be split constantly. Although wire fences began to be used as early as 1850, barbed wire did not really begin to replace the picturesque split rail fence for 30 years. During the first year on a new pioneer farm, trees were commonly girdled and left to rot, or were simply burned to get them out of the way, leading to terrible losses of useful timber.

What may seem to be incredibly stupid abuses today were simply part of the frontier heritage of the 18th and 19th centuries. Many of the earliest settlers viewed the forest and many of its inhabitants as the enemy, as a wilderness to be destroyed and conquered. With their dark monotony, trees shaded the ground and prevented good pasturage. They gave shelter and concealment to the Indian savage, and instilled claustrophobia in many who had only recently arrived from European countries, where the land had been subdued, cleared, and farmed for a thousand years. In a logical extension of this view, any forest wildlife that was not directly useful to the settlers was considered vermin and destroyed without second thought.

As a result of these many demands and wasteful practices, nearly all marketable timber originally in the state was removed by 1910.



The State Historical Society of Missouri, Columbia

Nearly all marketable timber originally in the state was removed by 1910.

Production in Missouri sawmills dropped 80 percent and fear of a wood shortage grew, rather similar to more recent oil shortage scares. While its most immediate effects on the human population were alleviated by development of coal and oil as alternate energy sources, as well as a continuing supply of building timber from western and northern forests, loss of woodland habitat did immeasurable damage to wild animal populations. Combined with market hunting, it is surprising that any wildlife survived at all.

As the population of Missouri continued to expand at a boomtown rate, the subjugation of the environment proceeded with equal gusto. Reliable supplies of beef from the western range were not to be commonplace until long after the Civil War, so wild game shouldered the burden of a hungry populace. While considerable game could still be found deep in the southern Ozarks, the last deer kill for decades to come was reported in Boone County in 1860, and, in 1862, 14 deer were killed in Lincoln County, rumored to be the last seen in that area for many years. Similar shortages became obvious among populations of turkey, prairie chicken, ruffed grouse, otter, beaver, and most other valuable species. Prodded by the incentive of intermittent bounties, the continuing loss of predators diminished any effect those animals may have had in controlling small mammal populations, and minor plagues of destructive rodents occurred.

While market hunters removed wildlife directly during the 19th century, the almost total removal of forest and plowing of land eliminated the cover and food necessary for populations to reproduce and recover. The use of wood for virtually all phases of development, coupled with the pioneer habit of clearing forest simply to be rid of it, brought wildlife populations to extinction or near-extinction levels.

Development And The Ozark Forests

In Missouri, talk of wildlife, wood, and forests generally entails a discussion of the Ozarks, because these subjects will always be inextricably linked. Covering more than 60,000 square miles, most of the Ozark region lies within the borders of Missouri. However, the upland also just barely touches southeastern Kansas, passes over the northeastern corner of Oklahoma, and extends along the northern tier of Arkansas counties. A very small part of southern Illinois, called the Shawnee Hills, is sometimes considered to be Ozarkian. The rugged topography of the Ozark uplift has had marked influence on its human cultural development, as well as on its floral and faunal development. Not only were Ozark plants and animals somewhat isolated from surrounding biological regions and free to evolve on their own, but human inhabitants were also set apart and often bypassed by progress in technology, agriculture, politics, and religion. The very same geographic isolation that first generated hundreds of endemic species of plants, fish, and amphibians, also isolated the Indians, and has been fundamental in creating the lore and character of the modern, yet "primitive" Ozark "hillbilly" culture as well.

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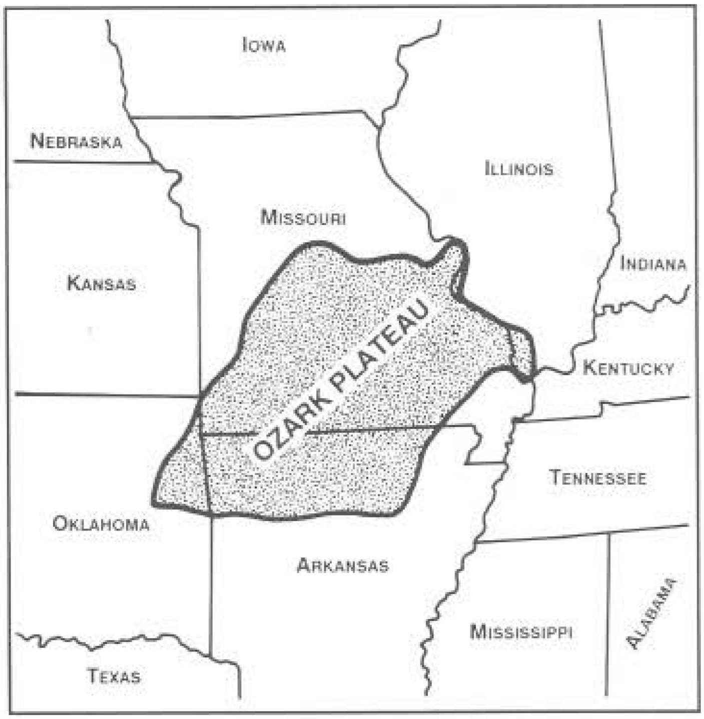


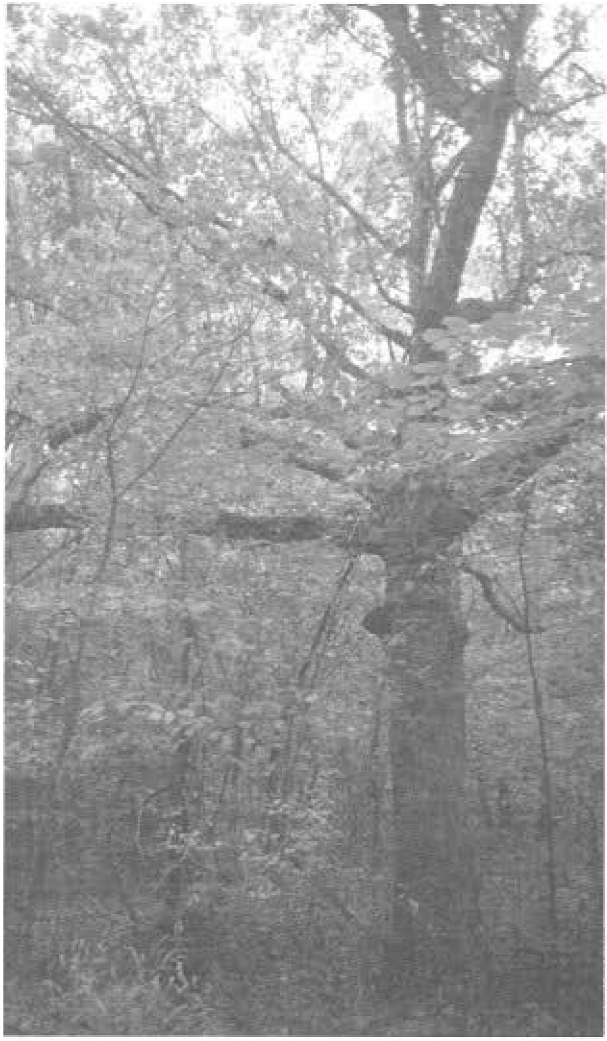
Artifacts from Paleo-Indian sites in the Ozarks a thousand years ago attest to the slow rate of artistic and technological exchange with the advancing tide of Mississippian culture that occurred in the rich river bottoms. The extensive trading networks of Mississippian people seems to have largely sidestepped the rugged terrain and the old-fashioned Woodland society of the Ozarks on its way to the Appalachians, Gulf Coast, Great Lakes, and Desert Southwest. While many Mississippian advances, such as the strengthening of pottery with fragments of shell, eventually appeared among Ozark Indians, most of their advanced technologies were not suitable to the relatively harsh conditions of the hill country. The vast farmlands, large towns, great mounds, elaborate pottery, and artwork of the tribes encountered by De Soto were not seen to any extent among Ozark Indians.

People in the Ozarks were described by early Spanish as living in poverty. Endowed with few benefits of the advanced technology available to the urban culture of the great river valleys around them, Ozark Indians had far fewer permanent effects upon their environment. Savanna and prairie vegetation among Ozark forests are the chief reminders of Indian presence. Their lives most nearly approached the overly romantic "as-one-with-nature" theme often expressed by later generations of admiring Europeans. However, it was contact with those Europeans that provided the post-contact Ozark Indian with the tools and motivation that would lead to the initial devastation of upland wildlife. Furthermore, Ozark Indian populations burgeoned for a time as eastern tribes were forced into Missouri by expanding European and American immigration. The combination of increased levels of technology and population, then as now, had very serious environmental impact.

When settlers first began entering the primitive Ozarks, about three-fourths of the upland was covered by trees: dense forests on the moist, sheltered northern slopes and cove-like valleys; parklike savannas along ridges and most southern slopes; and prairies and glades on the broadest plateaus and most exposed south-facing slopes. Small and scattered in eastern counties, grasslands covered about half of the western Ozarks. Along its western boundary, the forest was entwined, fingerlike, with the grassland biome. It is clear that Indian fires were instrumental in the creation and maintenance of these relatively small grasslands, as well as the more extensive savannas of the Springfield Plateau and other relatively open areas in the Ozarks. Old-timers regularly commented on the invasion of forest into these grasslands after the Civil War. By then, long after the departure of the Indians, annual grassland and woodland wildfires had been curtailed somewhat. In addition, decades of plowing, fencing, and road-building had begun, creating a moderately effective system of firebreaks.

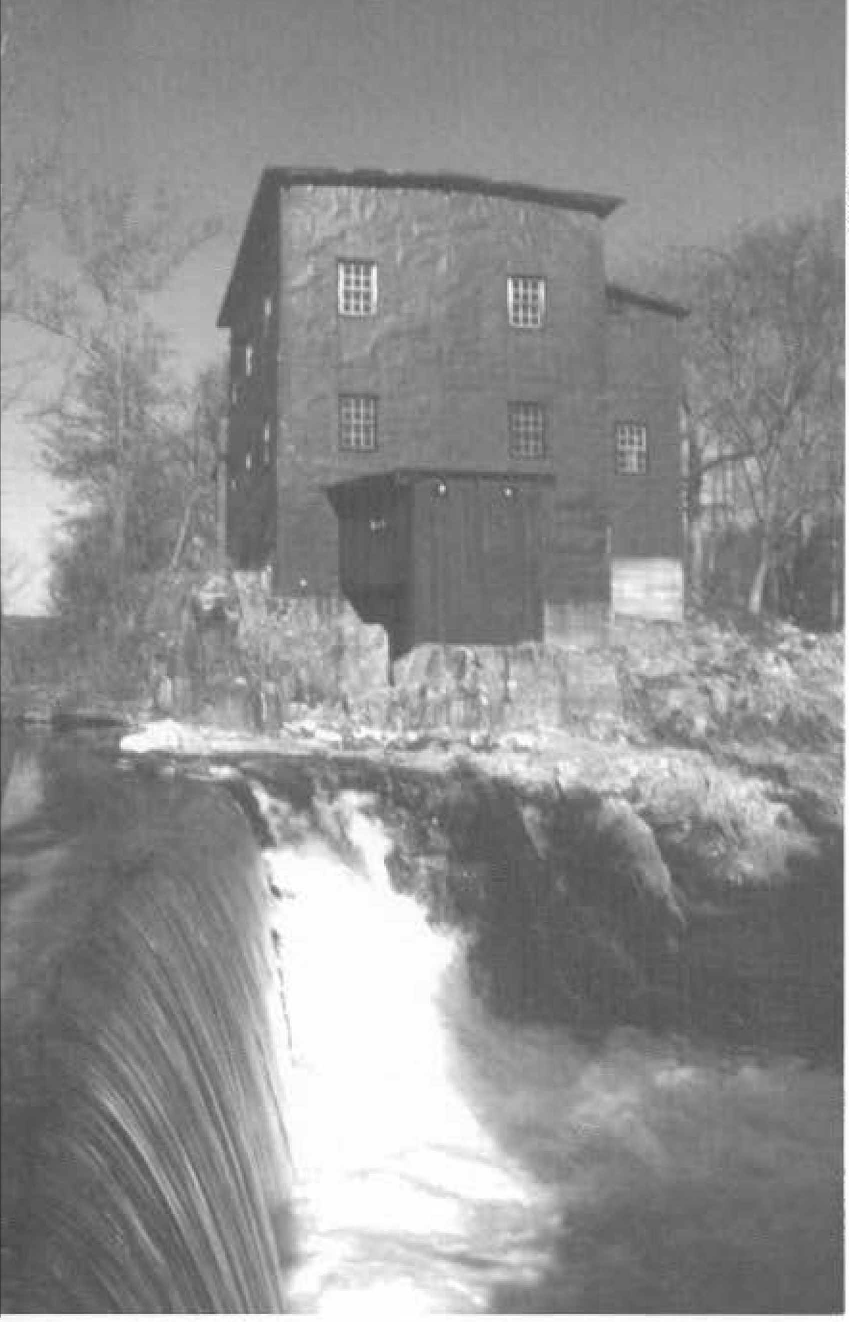
Early Ozark settlers were forced into a totally independent subsistence lifestyle by a stifling combination: the lack of a broad economic base and a rapid means of transportation. They naturally selected home sites on the best available soils where they could extract everything they needed. The entire Springfield Plateau, the Ozark prairies, and the flat interior uplands were populated early on, as were the wide basins of the Fredericktown, Arcadia, Belleview, and Farmington valleys. Most were completely settled by the time of statehood. The lack of stumps or other signs of forest on these old upland and valley farm sites is mute testimony to thousands of years of Indian fires and nearly two centuries of continuous agriculture on their deeper and richer soils.

Limited, single-family cultivation was the only type of farming possible among the long, narrow valleys, hogback ridges, and small bottomlands of the deeper Ozarks. Because of the small scale and short life expectancy of the operations that such areas could support, the use of these sites has been sporadic but continual right up to the present. Many small Ozark bottomland farms have been periodically abandoned and overtaken by second growth, only to be cleared again by another generation of bright-eyed settlers, the most recent coming in the 1960's, 70's, and 80's. Scattered among today's uniform forests of straight, young trees, a few grand, broad-crowned oaks with low, spreading branches stand as witnesses to the open, sunny conditions that prevailed during earlier periods of farming and grazing. While virtually all original forest was removed, these few individual trees were allowed to shade a pasture or yard.


Jon Hawker

Old, wide-spreading oaks now mark early homesites where a few trees were left for shade.

As in Indian times, transportation and communication were significant factors in retarding American development of the Ozarks. Riverboats, so necessary to the shipment of goods and people along the Missouri-Mississippi-Ohio network, could not penetrate far into the interior. Limited riverboat use was made of the White River and the lower reaches of the Gasconade, Meramec, Black, and Current rivers, but generally only with smaller craft, and then chiefly during periods of high flow. Because they were of only minor use for transportation, many of the streams, especially those with high-gradient stretches or with large, permanently flowing springs, found other uses. Many were ponded behind low dams to build a sufficient "head" of water for powering milling operations. Most such mills, intended for grinding grain, sawing lumber, or operating small factories, were quickly replaced by portable steam engines that could be set up on site, then moved as needed. A few of the rustic water-driven mills remain in varying states of repair in the Ozarks, some still in limited operation to pay homage to this more primitive period of technology. They include: Dillard Mill, in Dillard Mill State Historic Site on the Huzzah


Nick Decker

Early settlers in Missouri took advantage of the clear streams to power grist mills, such as this one in Dillard Mill State Park south of Steelville.

Creek in Crawford County; Montauk Mill on the Current River in Montauk State Park, Dent County; Bollinger Mill State Historic Site on the Whitewater River in Cape Girardeau County; and the old Red Mill at Alley Spring in Shannon County.

Although rocky Ozark streams may have had limited boat travel, virtually every permanent stream became a means by which the steadily growing demand for railroad ties could be met after 1860. Hundreds and sometimes thousands of ties were roped together in huge rafts and floated to market or to the nearest railroad siding during the great timber boom of the last half of the nineteenth century. In fact, the use of Ozark streams to float large rafts of ties was the basis for a landmark 1954 Missouri Supreme Court decision, Elder vs. Delcour, that judged all Missouri streams to be navigable and thus not open to private ownership. It was this propitious decision that has allowed Missourians access to all Ozark streams for canoeing and fishing, even though the lands on either side could be held privately.

Goaded by huge quantities of Ozark timber and minerals, but frustrated by the lack of transportation, entrepreneurs eventually responded with a system of railroads. The first railways to snake their way into the Ozarks were the St. Louis and Iron Mountain from St. Louis to Pilot Knob in 1858, a later extension of that roadbed from Mineral Point to Potosi, and the Southwest Branch of the Pacific Railroad of Missouri. This feeder left the main line at Pacific and reached Rolla in 1861. Most other rail lines in the state quite sensibly skirted the rugged terrain of the Ozarks. A scattering of short freight railroads and spur lines was constructed to serve the developing mineral and timber industries, but most were abandoned as a district's resources were depleted. Many of these old grades can still be found winding through the hills and along valleys. Even with their short lifespan, these railroads brought major changes on the landscape, both directly and indirectly. The coming of the railroads not only reflected the expansion of a population in need of transportation, it also accelerated that very expansion by opening new markets and bringing in immigrants.

This old lithograph shows a stagecoach traveling a plank road, forefunner of today's paved highways. While in vogue, plank roads consumed great quantities of timber.

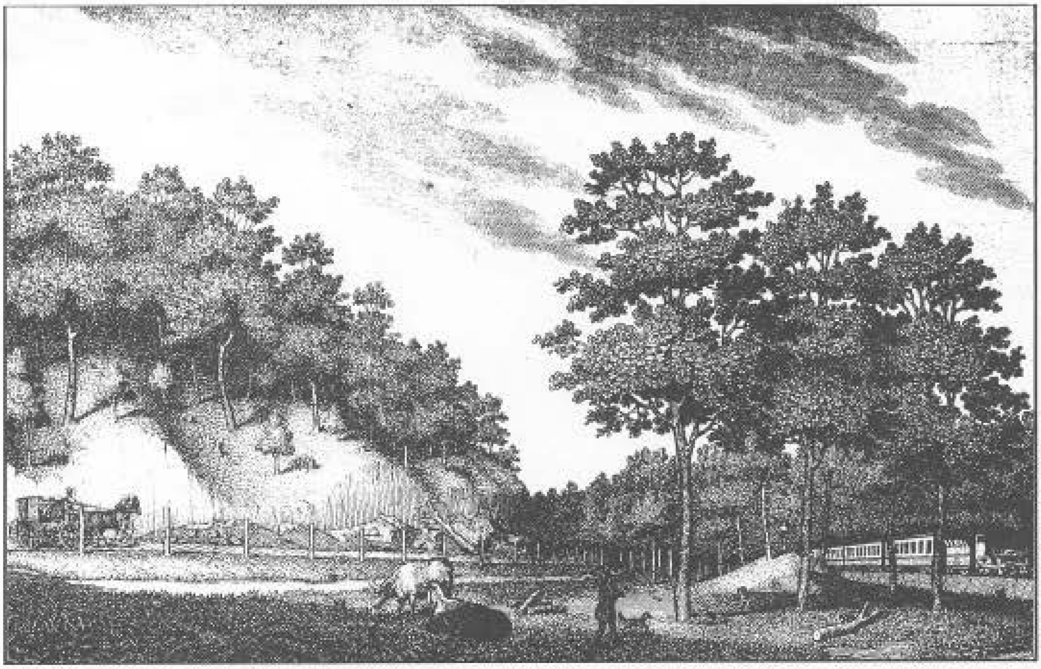
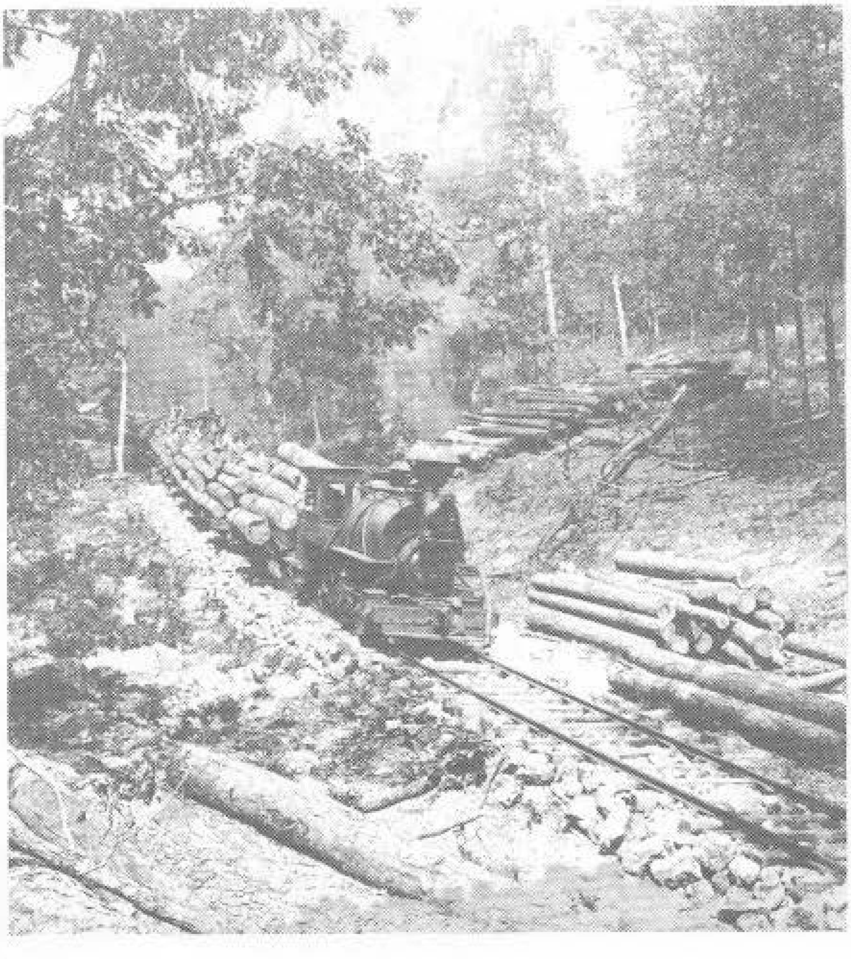


Illustration from Swallow, 1855

Even as late as the mid-1800s overland travel was still extremely difficult and hazardous in the Ozarks. Only a scattering of roads had been carved through the hills and most were strewn with boulders and tree stumps. To compound the difficulties of travelers, there were few ferries and no bridges until nearly the turn of the 20th century. Even by 1850, stage lines had expanded to serve only 500 miles of roadway. Although a flurry of construction had begun on plank roads, most were toll roads and served only to connect local mining or timber districts with nearby rivers or railheads. The movie and television image of cowboys and wagons streaking along in a cloud of dust and gunsmoke, on roadways graded so smoothly that the good guy picks off the bad guy 100 yards away, at 24 miles an hour, is a product of the imaginations of Hollywood directors. Such roadways were not widely available until the coming of the automotive age. Considering the alternatives, it was inevitable that railway transportation became the focal point of early economic development in the Ozarks, as elsewhere, and assumed responsibility for the transport of massive amounts of resources away from the region.

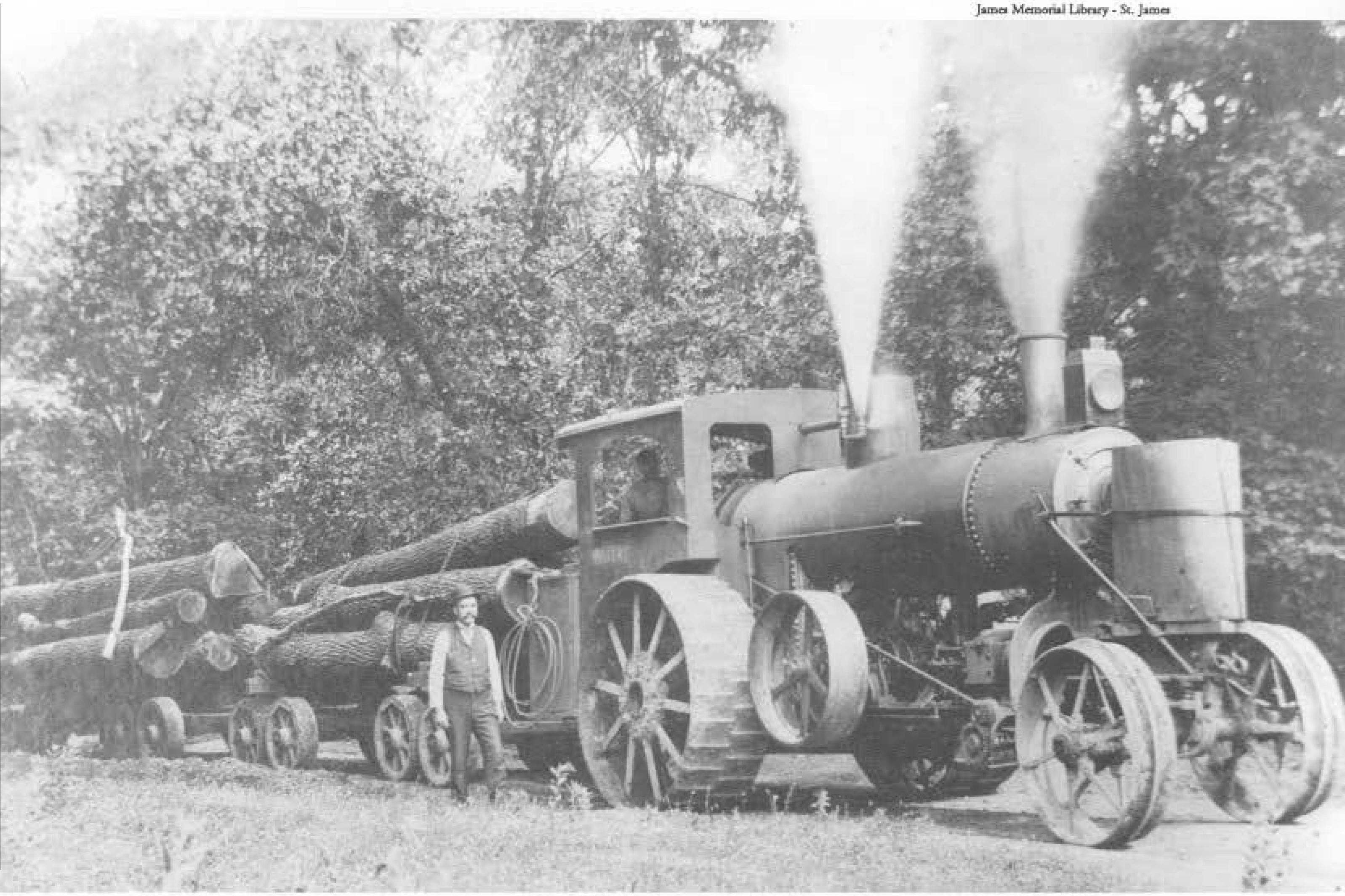
Train cars loaded with logs leaving Grandin's sawmills, believed at one time to be the largest in the world.



Missouri Department of Conservation

The physical growth of the railroads depended heavily on the development of the very timber industry that it grew to serve. Small-scale sawmills had begun operations

James Memorial Library - St. James



Steam power gave a boost to the timber industry through its capability to move heavy loads to the mills.

during the first quarter of the 19th century. Powered by hand or water, such mills served only the local market and removed little timber. By the 1880's, however, lumber company boom towns, each employing hundreds of axmen, were in full swing at Winona, Birch Tree, Grandin, Leeper, Doniphan, West Eminence, and dozens of other locations. In its heyday, the sawmill at Grandin was the largest in the nation, and probably the entire world.

For 40 years the large, insatiable timber companies stripped virtually every marketable tree from the Ozarks. Their endowment to Missouri was a greatly depleted natural resource, a drastically altered environment, and just as importantly, a large, essentially jobless population. As in other "frontier" enterprises, the approach used was "cut out and get out." When the trees ran out and production of lumber dropped, companies folded and left. Many of the suddenly unemployed millworkers and sawyers chose to remain in familiar territory. Many purchased cut-over land and attempted to make a living at farming. With no steady income, these people lived hand to mouth, digging ever deeper into the region's dwindling wildlife and forest reserves. Eventually large numbers of these poorly trained and ill-equipped farmers, as well as many defunct lumber companies, went bankrupt and lost their lands because of tax delinquency. Much of this property would later be purchased by the state and federal governments for state or national forests, or for wildlife areas.

During the era of decline, forest management was essentially unknown. Every sprout was cut as soon as it reached minimal marketable size for barrel staves or charcoal production. Open grazing and regular burning to improve cattle forage were the rule. Nearly all settled areas were burned cyclically every three or four years, a practice that continues in limited circumstances even today. For the hill people, the forest was still the enemy, even in the middle of the 20th century. Because of the massive soil erosion that accompanied clearing and burning of the land, and the resultant slow, stunted regrowth of sprouts, neither farming nor forest products were able to provide much of a living. The subsistence-level Ozark economy that had flourished for thousands of years was barely possible now. Life could operate at only the very lowest of levels because of the greatly diminished availability of resources. Beaten and hopeless, many people simply drifted away from the Ozarks.

While the trees were relentlessly attacked from all quarters, the smaller plants of the forest received a similar thrashing. Open grazing and fire, and the light-encouraging effects of logging, severely damaged populations of deep forest wildflowers far more than they would have the sun-loving species of prairie, savanna, and glade. Bathed by intense light, many delicate plants could have survived only along streams, at the bases of cliffs, or in the darkest ravines. It is likely that the general distribution of forest species on hillsides and along ridgetops shrank tremendously during this period. Furthermore, while market hunting decimated animal species, rootdiggers and herb collectors traveled the draws and valleys pulling out ginseng and other medicinals for sale, just as they do today. It is possible some forest plants might have disappeared from the Ozarks at this time, and perhaps some rare relict and endemic species could have been driven into extinction. Since a complete survey of Ozark vegetation was not completed until well into the 20th century, and few knowledgeable people were documenting the rapid biological changes, we shall never know for certain.

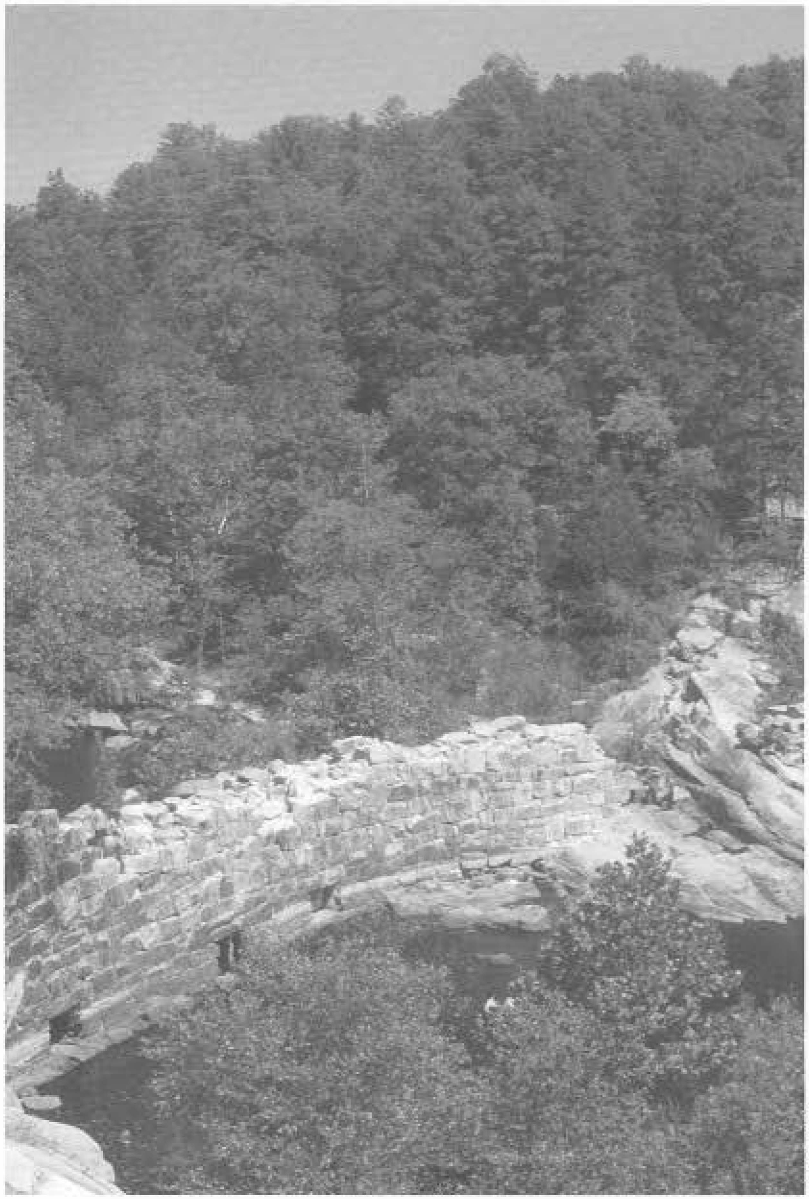
The ruggedness and isolation of Ozark terrain gave brief protection to its resources, but the advent of railroads soon overcame these obstacles. Before the Great Depression hit, its most valuable forest resources had all been stripped.

The Legacy Of Antoine De La Mothe Cadillac

While uncontrolled and improperly managed timber and farming operations destroyed habitats over broad areas, mineral development tended to have a more local, but more intense impact. One of the most important mineral centers of North America, Missouri offered huge quantities of lead, zinc, barite, and iron, along with limestone, dolomite, silica sand, fire clay, coal, and the ubiquitous chert gravel of the Ozarks. In addition, significant quantities of silver, manganese, copper, cobalt, nickel, and tungsten have been mined periodically in the St. Francois Mountains. Some of these operations, such as the spectacular Silver Mines mine and dam site on shut-ins of the St. Francis River in Madison County west of Fredericktown, were briefly prosperous. Other mines, such as one carved into the base of Bell Mountain nearby, never seem to have gone anywhere. Ironically, Missouri's mineral resources do not seem to have brought it the fame or status of other mining states, like Colorado, Nevada, or Arizona. While the state has had many company towns that depended on one mineral or another, each leaving its own peculiar stamp on the landscape, there has been no legendary "Virginia City."

Although the discovery of lead by de la Mothe Cadillac may legitimately be regarded as the commencement of mining in Missouri, Indians had in fact utilized Missouri rocks and minerals for thousands of years before the French arrived. Native diggers had scraped small pits in south-facing Ozark hillsides in search of fresh chert nodules to fashion into tools. Still obvious in such places as West Tyson County Park in St. Louis County, such diggings provided workable material for arrowheads, knives, scrapers, drills, and other implements. From sites scattered around the St. Francois Mountains, Indians also extracted lumps of durable hematite for shaping into plummets used as bola stones (weights tied at the ends of thongs thrown to entwine prey), and for grinding and mixing with fat in the manufacture of red paint. Basalt and other hard, dense igneous rocks were ground and polished into atlatl weights (often called "bannerstones") attached to the handle end to offset the weight of the dart when it was thrown, as well as hammers, tomahawks, adzes, and other heavy cutting tools. Various kinds of sandstone were used for abrasives and grinding surfaces. Pleistocene deposits of agate, quartzite, gneiss, and other glacial erratics provided workable stone that was as beautiful as it was durable.

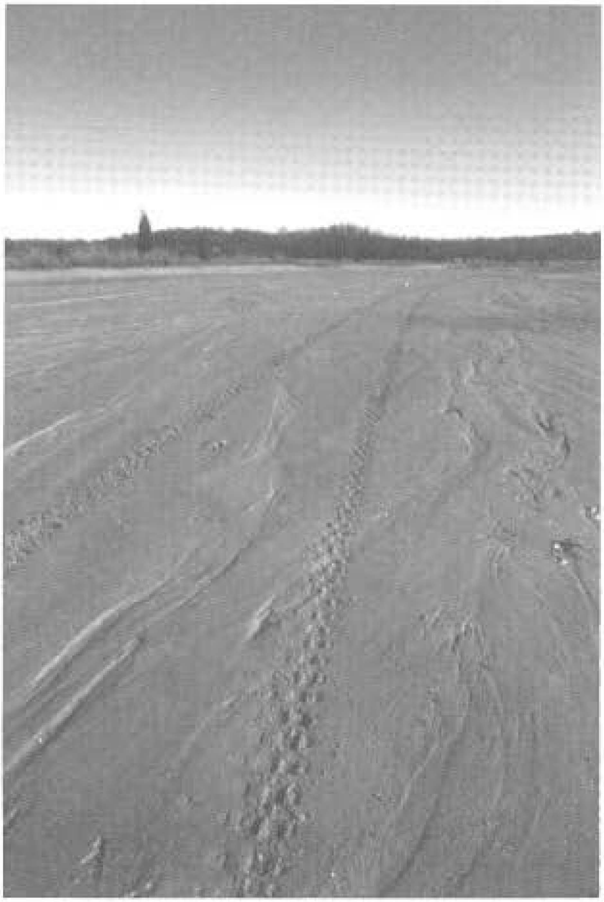
Despite such small-scale Indian workings, lead mining may truly be regarded as the first of Missouri's hard-rock mineral industries. Digging by hand with picks and shovels, the first Missouri miners extracted only the most accessible deposits. The lead they sought was in the form of large, discrete crystals of almost pure lead sulfide, or galena, dispersed as silvery cubic lumps in the sticky red clays of Ozark hillsides, all that remains of the Paleozoic rocks in which the lead mineral originally crystallized. The small, easily extracted surface deposits of lead worked by the French as early as 1730 were quickly depleted. Except for the towns that grew in their wakes, the scattering of hand-dug pits, and the ruins of a few shot-towers, these small-scale operations left little impression on the land.



Jon Hawker

The granite-block dam at Silver Mines in Madison County was breached to free the St. Francis River, once harnessed to power the mine's milling operation.

Around 1800, Moses Austin brought efficiency and engineering skills to lead mining. Austin's Mine UCS85 Breton was the first with a deep shaft and his advanced smelters could extract twice as much of the heavy metal as any of his competitors. In 1809 Austin founded the town of Herculaneum and built two shot towers high on the Mississippi bluffs of present-day Jefferson County. Herculaneum soon surpassed Ste. Genevieve as a lead depot. More than a century later, the town was still home to the nation's largest lead refinery, operated by St. Joe Lead Company (now the Doe Run Company). Unfortunately for Austin, the demand for lead was as fickle then as it is today and his fortunes faded with its price. Still searching for a dream, he turned his attentions to establishing a Missouri Province in Mexican Texas. His untimely death, in 1821, cut his plans short. His son, Stephen, fulfilled the dream by leading 300 Missouri families to found an American colony in Texas, the first of many restless Missouri



Nick Decker

Near Bonne Terre, in St. Joe State Park, dune buggies, jeeps, and dirt bikes scream across waste flats of crushed dolomite, the legacy of more than a century of lead mining.

transplants to the West. Missouri lead mining continued in Austin's absence.

Over the next 250 years, mechanization allowed the development of larger, deeper, and more diffuse deposits in the Old Lead Belt around Bonne Terre, the Tiff District near Potosi, the Tri-State District at Joplin, the Central Mineral District southwest of Jefferson City, and the New Lead Belt around Viburnum. Missouri has been first in lead production in the nation during most of the last two centuries, and still produces about 90 percent of all U.S. reserves. Considerable amounts of copper, silver, and zinc (the state provides roughly 75 percent of the nation's total zinc production, principally from the mineral sphalerite) are also recovered from lead-bearing rocks.

Because the lead mineral in these deposits is dispersed thinly through the matrix that holds it, enormous amounts of rock must be removed and crushed to recover the metal. During refinement, lead operations produce huge amounts of pulverized rock slurry that were first spewed into mountainous piles of "tailings," but now are piped into valleys, filling mile after mile with the sterile gray sand. Once the richest ores have played out, the mines close and move on. As a result, the pitted and pockmarked Tri-State District around Joplin looks like a battlefield or an abandoned gunnery range. Back at Bonne Terre, in St. Joe State Park, dune buggies, jeeps, and dirt bikes scream across waste flats of crushed dolomite, while an occasional hang glider soars down the adjacent tailings heaps. It is unlikely that anyone will develop a more appropriate use for these manmade deserts.

In addition to lead, two principal forms of iron ore have also been mined in the Ozarks: the small filled-sink deposits that collected in ancient sinkholes, and the massive hematites and magnetites that crystallized in the igneous rocks of the St. Francois Mountains. A century after the initial period of lead development, in 1815, the first iron furnace west of the Mississippi River was established by Ashebran near the entrance to Stout's Creek Shut-in in Iron County. Another iron smelter and mill was established on Furnace Creek west of Potosi in 1823. Both of these operations utilized rich St. Francois Mountain hematites. However, most early operations, such as the James foundry at Maramec Spring in Phelps County, utilized ore from ancient filled-sink deposits. Predominantly small, most of these ironworks

James Memorial Library - St. James

Maramec Spring Foundry near St. James, powered by the waters of a huge spring, operated for 50 years.

disappeared quickly as accessible ore dwindled or the economy faltered. Their small size and short life span limited the scale of digging, tailings, and slag; however, each smelter's demand for charcoal resulted in the loss of hundreds of thousands of acres of Ozark timber to support the process. Iron- and steelworks typically consumed many more acres of forest than lead smelters. The higher melting point of iron required a much hotter furnace and demanded huge amounts of charcoal rather than firewood as fuel. Initially, charcoal was also necessary as the carbon source for steel production. The stunted forest around St. James is chiefly the product of two generations of charcoal burners, who kept the furnace fires burning from 1829-1879.

To make charcoal, woodcutters brought in cords of wood all winter when the ground was frozen. In the summer, the logs were piled in stacks some 40 or 50 feet in diameter. To make charcoal, the fire had to burn with just the right amount of oxygen. Heat was necessary to drive off the volatile elements in the wood and convert it to charcoal, but too much air ignited the wood and destroyed the product. It was up to the **charbonniers**, expert charcoal burners who were much in demand, to cover the wood with enough soil to slow the fire, but not enough to suffocate it. The charbonniers tended their fires carefully, sprinkling them with water to maintain the correct temperature. Eventually, the cost of converting trees to charcoal forced iron mines to ship their ore to Carondelet and St. Louis, once the rails had been laid, where a ready supply of Illinois coal could fuel furnaces and supply coke as the carbon source for steel manufacture. Today, large brick and concrete ovens are used to convert Ozark oak and hickory to charcoal for the family cookout.

Two flourishing communities, Iron Mountain and Pilot Knob, resulted directly from the development of Ozark iron deposits. The ironworks also stimulated the building of roads and railroads to transport supplies to the mines and iron products away. Heading north, Highway 19 largely follows the original shipping route from Maramec Spring to Hermann. Heading east, Highway 32 traces the 1851-53 plank road designed to carry materials back and forth between Iron Mountain and Ste. Genevieve. This plank road, like a flurry of others constructed during this era, was built of four-inch planks laid across parallel logs. The enormous cost of building the Ste.

Genevieve-Iron Mountain toll road - about $200,000 - and its subsequent maintenance was never recouped. When the St. Louis and Iron Mountain Railroad, built in part to take advantage of the developing mineral industry, bypassed Ste. Genevieve, the plank road became obsolete and the old French town's hopes of continued prosperity sank.

Jerry D. Vineyard

Lead ore occurs a thousand feet or more underground along Missouri's famous Viburnum Trend. To mine and process the ore, extensive surface facilities are built and shafts are dug into the ore zone.

In stark contrast to the small filled-sink deposits of the last century, large-scale, heavily mechanized iron operations at Pea Ridge and Pilot Knob work (when in production) in massive igneous formations at depths of a thousand feet or more. Because of the high rate of recovery from Missouri's rich ores, the huge amounts of tailings generally associated with lead mining have been largely avoided. The fact that production has been of shorter duration and in smaller quantities than Missouri's lead mines has also helped reduce impact on the environment. In part, current iron mines leave less evidence on the surface because processing is no longer on-site. This eliminates much of the air, water, and land pollution problems that usually plague metal refineries. In addition, as with other metal industries, Missouri's iron mines are delicately tied to the world market. Generally the state's ores are not in a very competitive position because of the high cost of deep subsurface mining. Larger open-pit mines overseas, coupled with low-cost labor, force Missouri mines to shut down operations whenever the market is weak.

For a brief time Missouri, and the St. Louis and Mexico regions especially, were world leaders in fire brick and refractory (the highest grade fire brick) manufacture because of locally abundant clays. It is indeed heart-warming for a traveling Missourian to see "Laclede" fire bricks or refractories lining the furnaces of abandoned smelters and refineries in old mining districts in various western states.

Unfortunately, we are unlikely to ever see similar Missouri refractories lining the boilers of World War II warships and Liberty ships, the Apollo launch pads, or thousands of less well-known uses, where most of our best clay resources wound up. The first Missouri fire brick was manufactured about 15 years before the Civil War, and as mineral development stimulated westward expansion, St. Louis became the chief supplier of furnace bricks for the West's metal refineries and smelters, and for the rest of the world. These early brick manufacturers did not utilize the highest grade fire brick material, called diaspore. Diaspore was not discovered and formally identified until 1917. The diaspore "clay," which is not actually a true clay, is mineral with high aluminum oxide content. The purest diaspore melts at an incredible 3300°F, far hotter than the hottest refinery or blast furnace ever reached, so refractories manufactured from diaspore were supremely suited to such uses.

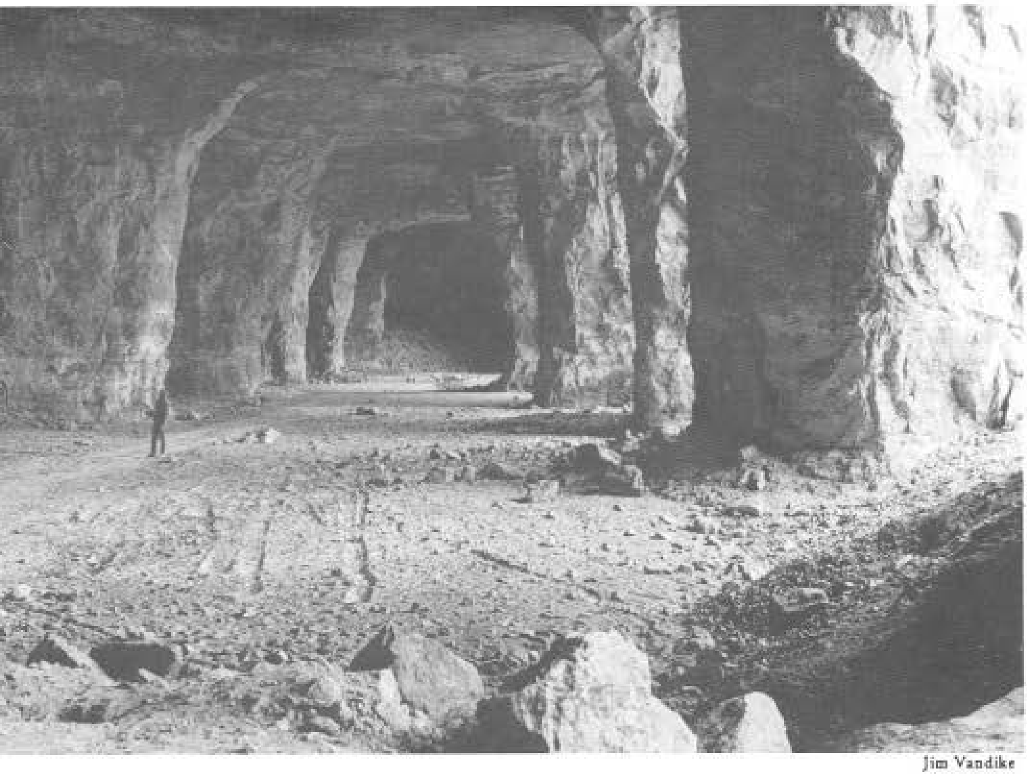
The mining of diaspore in Missouri, which ended after only 30 years when the last workable deposit was hauled away, was never particularly widespread because of the restricted conditions under which the mineral formed and collected. The most valuable fire "clays" accumulated in sinkholes originally dissolved into Ordovician-age rocks of the northeastern Ozarks by acid swampwaters during the Pennsylvanian. As various minerals collected, water seeping down from the surface gradually dissolved and carried away all others, leaving only the insoluble alumina. This process, called laterization, is very much the same that today destroys tropical soils for agriculture once the rain forest has been removed. When mined, the diaspore was often found mixed with considerable quantities of the mineral kaolinite, the typical flint clay used for brick manufacture before and since, and so-called because it fractured with the same shell-shaped, or conchoidal pattern as flint or chert. While useful in its own right for the production of a lower grade fire brick, the kaolinite was often discarded. Abandoned clay pits from a century of clay-mining operations now dot all of Gasconade, and parts of Osage, Franklin, Maries, Phelps, and Crawford counties where the most valuable deposits were depleted by 1950. A sister district north of the Missouri River, centered on Audrain County, produced large quantities of kaolinite clays. Many areas around St. Louis, the largest lying between Tower Grove Park and Forest Park, were also mined for clay production. A small refractory clay site was worked for a time near Ellisville.

Other less valuable types of clay, those derived from Pennsylvanian, Devonian, and Ordovician sediments and shales, are still mined at nearly a dozen sites along the Missouri River from St. Louis to Kansas City, and south along the Mississippi River to Cape Girardeau. The ancient mud is converted to drain and roofing tiles, flower pots, building brick, stoneware, and pottery. A few sites along Crowley's Ridge in the Bootheel produce absorptive clays used in floor sweeps and cat litter. The mining of these lower grade forms of clay has been intense enough to rank Missouri at the top or among the top three clay producers in the nation.

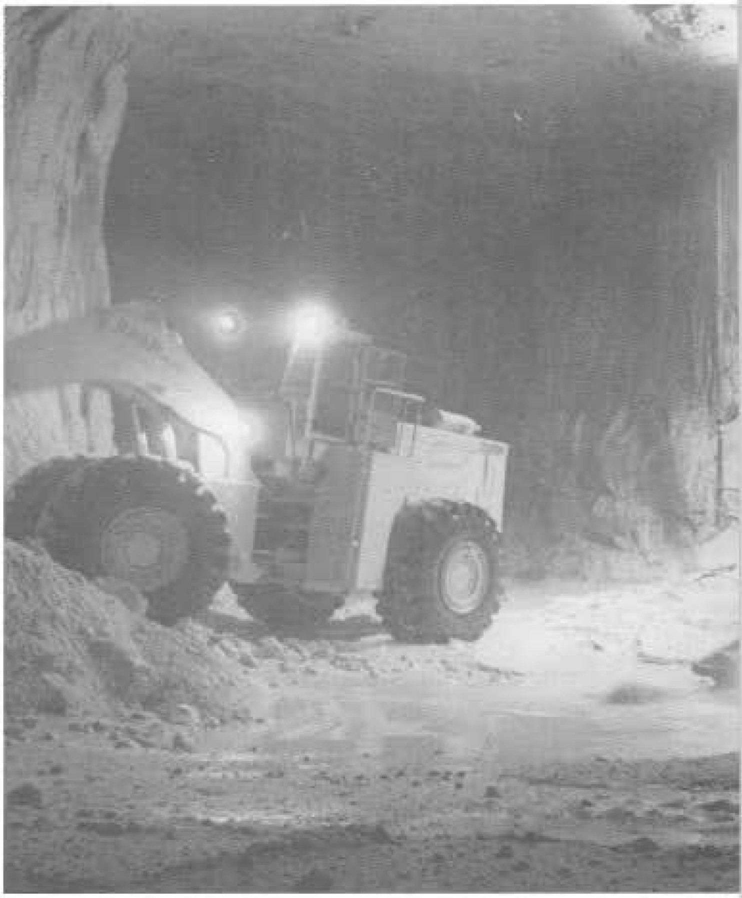
Many early settlers worked in the lead and iron mines of the Ozarks, but others came to farm, work in mills, or live off the land. Whatever brought them to Missouri, all pioneer families acquired land and built dwellings, requiring stone for hearths, chimneys, doorsteps, and foundations. At first, such rocks would have simply been dragged from a nearby creek, off a glade, or pried from an outcrop, what we call fieldstone. As buildings became more permanent and more sophisticated, the methods of acquiring building stone improved as well. Using a shovel or a dragline, suitable strata of limestone, dolomite, or sandstone could be exposed by a single man, then extracted with wedges, an iron bar, a pick, and a sledge hammer. Roughly squared with hammer and chisel, the stone could be converted into foundations, steppingstones, and fireplaces. Today, many streamside bluffs and hillsides near old farmhouses bear the over-grown, shallow indentations of these small, hand-dug quarries. Only after population densities increased substantially did large commercial quarries prove profitable.

Large-scale quarrying of limestone, dolomite, shale, and sandstone is mainly confined to the northeastern edges of the Ozarks, along the bluffs of the Missouri and Mississippi rivers, and in the Springfield area, in places where agriculture is more intensive and stone and lime are required in huge quan-tities. The bluffs of the Big Rivers also provide easy access to the stone. Limestone that is not used as blocks directly for building, may be crushed to produce chat or aggregate in road construction, or else roasted with shale to make cement for use in concrete. Both limestone and dolomite are crushed and distributed as agricultural lime. From other bluff sites, as mentioned, suitable strata of shale have been mined for use in the manufacture of clay products. Sandstone quarries are largely in the white St. Peter formation and the high-grade sand extracted is destined for those uses listed earlier. To a limited extent, flagstone is quarried from other, more colorful strata.

Limestone mines and quarries produce the raw material for cement, crushed stone for road-building and concrete aggregate, and finely-ground aglime for farmers' fields.



Jim Vandike



Jim Vandike

The St. Peter Sandstone, quarried from open pits or mined from huge underground chambers, has made possible an extensive glass-making industry. Crystal City, south of St. Louis along the Mississippi River, was the center of glass-making for many years.

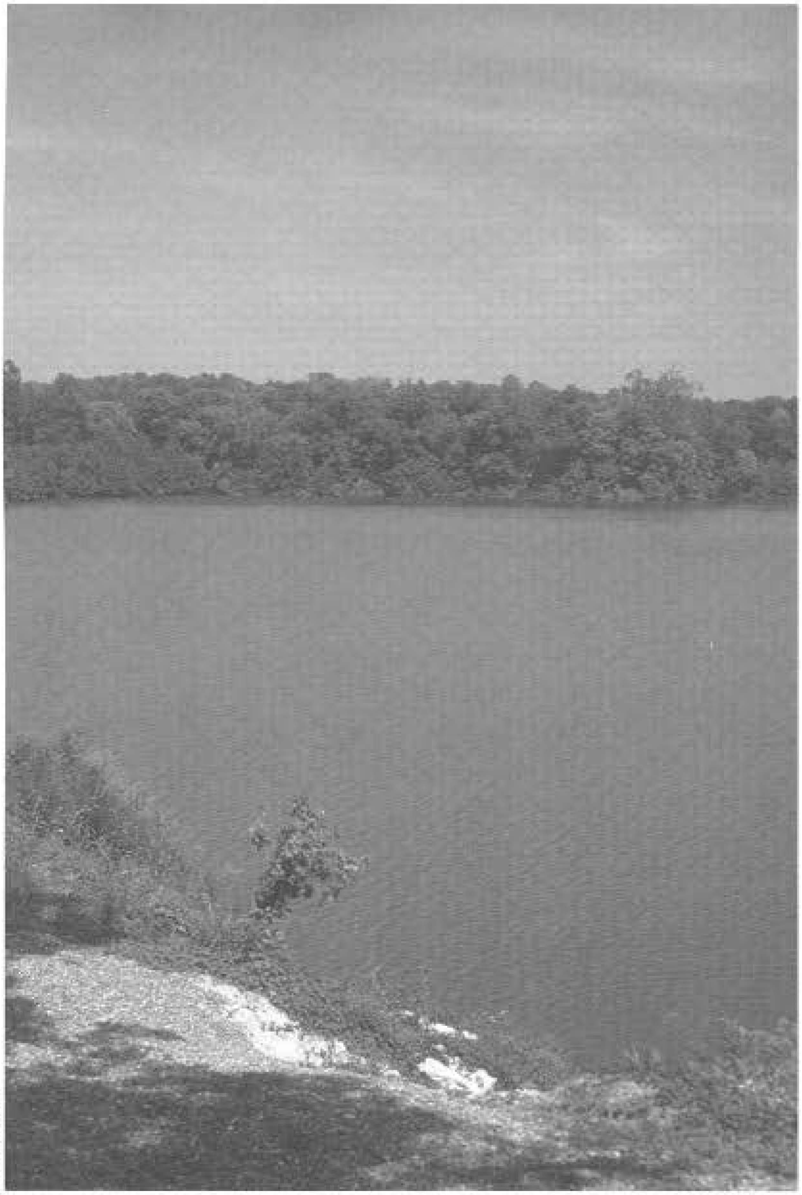
In general, quarrying has not had the same degree of overburden, tailings, or refining problems that are associated with hard-rock metal mining. Most of the rock is used as is, and only a small amount of unusable debris actually piles up on site. On the other hand, quarrying results in noise, window-rattling, and stifling dust and, especially in the production of cement from limestone, unavoidably corrosive dust and smoke. Energy-intensive glass and cement plants rightly seem to generate more concern over their effects on air quality than they do for their generation of solid waste. Of course, an inescapable result is that whole Missouri hillsides disappear en masse, to be spread thinly over the fields and on the roads of the Midwest, or to be converted into bottles. In any event, even though the effects of rock quarrying on the Missouri landscape can hardly be ignored, their impacts on flora and fauna seem to be among the most localized of the mining industries. Development of the state required incalculable amounts of crushed rock for the ballast of railroad beds, the paving materials of roads and driveways, and the aggregate in concrete.

For Missouri projects, sand and gravel have almost always been abundant and locally available. As a consequence, recovery pits are scattered far more widely than quarries. On various scales, and for varying periods, building materials operators have dug, dragged, scraped, sucked, and scoured sand and gravel from virtually every county in the state. Reclaiming the chert washed from Ozark hillsides by a century of uncontrolled erosion, many sand and gravel companies serve out-of-state as well as local markets. It is indeed strange to see common Missouri chert gravel sold as an exotic decorative stone by a landscape nursery in Chicago.

Pleistocene sediments are also reclaimed along the Mississippi River east of the Lincoln Hills, and even older Lafayette sands and gravels are bulldozed from sites along Crowley's Ridge. The durability and hardness of Missouri's weathered chert lends itself to roofing, road surfacing, and high-quality concrete, as well as stone mulch for landscaping. Most sand and gravel pits are sited along streams where the bulk of the raw material collects and sufficient water is available for washing. Once an operation has moved on, floods carry away some of the evidence. Nevertheless, thousands of acres of gravel pits have scoured river and creek bottoms throughout Missouri, muddied channels downstream, and lowered water quality for both wildlife and recreation. On the other hand, abandoned gravel pits often can be reclaimed as lakes suitable for wildlife, fishing, and recreation. A certain degree of site reparation is necessary, however, because the abandoned cables, dredges, piping, and unstable piles of aggregate can be hazardous to fishermen, hunters, floaters, campers, and hikers.

In some parts of the state another unique form of chert - an unusually porous silica mineral called tripoli - has been mined for totally different purposes. Formed from the aggregation of tiny crystals of insoluble silica in a matrix of soluble carbonate rock, like limestone or dolomite, the porous tripoli is left behind when the calcium or magnesium mineral dissolves away.

Tripoli was first mined near Tiff City and Seneca, in Newton County, shortly after the Civil War. The spongy, featherweight rock has been used intermittently as a polishing medium and abrasive, and for filtering drinking water supplies. Tripoli is sometimes called "tiff," although it should not be confused with the barium mineral referred to as "tiff" that is mined in Washington County. The mining of tripoli has never been a major industry, nor has its impact on the environment been severe.


Jon Hawker

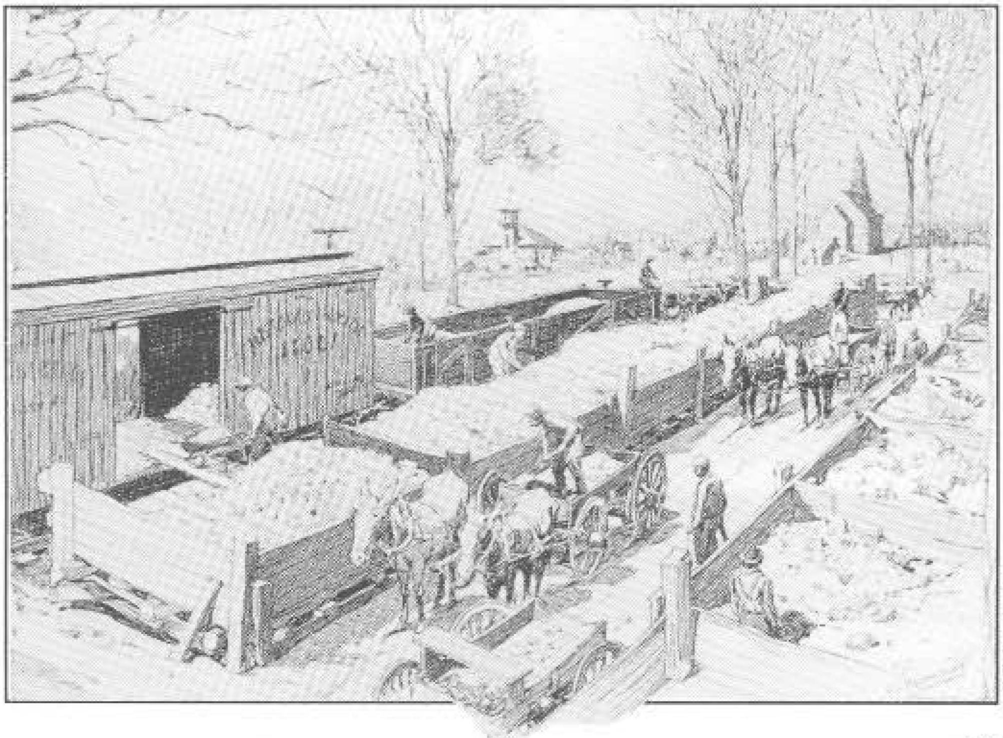
Some gravel pits can be reclaimed as valuable recreational resources, such as here in Simpson Park, St. Louis County.

The material usually referred to as "tiff" in southeastern Missouri, which is actually the mineral barite, composed of barium sulfate, has been a significant Missouri product for decades. For a time, Washington County was a world leader in the production of the heavy, brittle mineral. Barite is sometimes found in attractive orange-stained white crystals, with clay-colored blades jutting out at all angles, formations prized by rockhounds and mineral collectors. Occasionally, a ring of short blades form a flower-like barite "rose," commonly sold in roadside stands in Oklahoma. More often, only broken bits and pieces of the mineral are found dispersed in the gravelly clays of the Potosi Dolomite in Washington County and southern Jefferson County. The tiff originally crystallized in Cambrian dolomites. Because it was largely insoluble, like chert or lead, the barite was left behind in the red clays when the matrix of dolomite dissolved away. It is commonly found adhering to lumps of silvery galena and chert.

Although mined as early as 1857, in the same manner and at the same time as early lead workings, tiff was often discarded because it found few and relatively minor uses. More recently, barium has been used as a filler in paper to make a smooth-textured surface, in paint, and in the infamous milkshakes and enemas needed for medical x-rays. Around 1925, when petroleum emerged as a major energy source, crushed barite, chemically inert and heavy relative to most bedrock, was pumped down wells to hold in gas pressure and float well cuttings to the surface while the hole was being drilled.

For the first 100 years, while demand was minor, pick, shovel, and bucket were the only tools needed to mine "tiff." In the first quarter of the 20th century, lard cans on the buckboards of Model T pick-ups were the Ozark barite industry's chief delivery system. When the growing petroleum industry increased demand for drilling mud in the late 1920's and 30's, heavy mechanization took over. For the next 50 years, "tiff" mining laid waste much of Washington County. Bulldozers stripped out the surface rock, mud, and gravel from hillsides and valleys, and hauled it to central processing mills and washing plants. There the sticky, red clay and sand were rinsed out by swirling water piped in from a nearby creek or river, then swept into large collection basins, where the mud settled out. The heavier barite was collected and ground into powder for packaging. Almost totally depleted now, barite is no longer a major Missouri commodity and mining activity has diminished greatly.

The legacy of Missouri "tiff" mining is a landscape laid open as if lashed by a ship's cat-o-nine-tails. Without the slightest attempt at restoration, the broad settling basins, called


A barite shipping platform in Potosi, Missouri owned by the DeLore Baryta Company.

O.E. Berninghaus

This deep limestone quarry at Ste. Genevieve, the result of generations of blasting and hauling, supplies crushed stone for a variety of uses in the construction industry.

Dave Hoffman

tailings ponds, recover only slowly. Deeply scarred, nearly 20,000 acres of the stripped-out areas of Washington County have now filled with water, or have gradually been reclaimed by weedy vegetation and stunted forest. Some have produced red, muddy marshes or ponds valuable to wildlife. Others have eroded through or burst and flooded streams, causing heavy siltation and massive fish kills. Vegetation has yet to make a start on many of the heaps of rocky tailings.

Recovery and revegetation have been equally slow among the strip-mining industries that operate outside the Ozarks. Strip-mining for coal in Missouri has also disturbed thousands of acres of land. During the Pennsylvanian Period, swampy forests covered the land now divided among 63 Missouri counties. Over geologic time, the organic deposits beneath those swamps formed coal beds of varying thickness and at varying depths. In the 55 counties where these coal beds are reasonably close to the surface, they have been mined intermittently for nearly a century. Five principal fields have been producers, extending from Vernon and Bates counties north of Joplin, northeastward as far as Putnam County. The largest coal field is centered on Boone County in north-central Missouri, just outside the Ozarks. Most of Missouri's coals are soft, or bituminous, and high in sulfur. While not particularly clean, some are fairly high in energy content. Because of their high sulfur content, most of the state's present power-generating supplies are mined elsewhere, chiefly in Wyoming and Illinois. Nonetheless, over the years, approximately 100,000 acres have been surfaced-mined for coal, much of it valuable farmland. It was not until 1971 that coal, barite, clay, sand and gravel, limestone, and tar sand operations began mandatory reclamation of lands they had mined. Areas strip-mined before passage of the land reclamation law are reclaimed by the state, using money that accrues in an abandoned mined land fund.

Missouri has been a national and world leader in the production of several valuable minerals, notably lead, zinc, and iron. Development of the state's infrastructure has benefited from easily accessible deposits of necessary building materials, including sand and gravel, limestone and dolomite, sandstone, shale, and clays. As is true of all non-renewable resources, however, the short-term gains have not come without environmental cost. For nearly two centuries, the state has offered these commodities in exchange for temporary benefits, but until recently has not provided for reclamation of lands degraded by mining.

Slowing Missouri's Waters

By the 1930's, after a combination of logging, burning, careless farming, and mining had taken their toll for more than a century, the vegetation necessary to prevent soil erosion was largely gone. Intact forest could be found only in the most inaccessible places. Vast tracts of Ozark land had lost a quarter of its original soil cover. The disruption of drainage patterns had profound effects along most of the region's streams. Directly attributable to excessive runoff and erosion, water tables had dropped severely, wells went dry, springs ceased to flow, and many creeks simply vanished when it wasn't raining. Instead of soaking in, heavy rains caused great floods. The federal government, on the lookout for civil ways to pry the nation from the grip of depression, struck out in all directions at once. In the Ozarks, government agencies made plans to control the floods and bring the backwoods into the 20th century through a dam-generated rural electrification program.

While 19th century grist mill owners had constructed numerous small dams along dozens of small streams and across many large springs, few had tackled the larger rivers. These early, small dams had only minor effects on the natural system of the stream they straddled. They rarely interfered with wildlife, hardly interrupted the flow of water, and did little to alter the natural cycle of flooding. Even the first hydroelectric dams, like the one built in 1890 southwest of Joplin, at Grand Falls on Shoal Creek, were very small-scale and intended to satisfy only local demand, in this case the Tri-State Mining District.

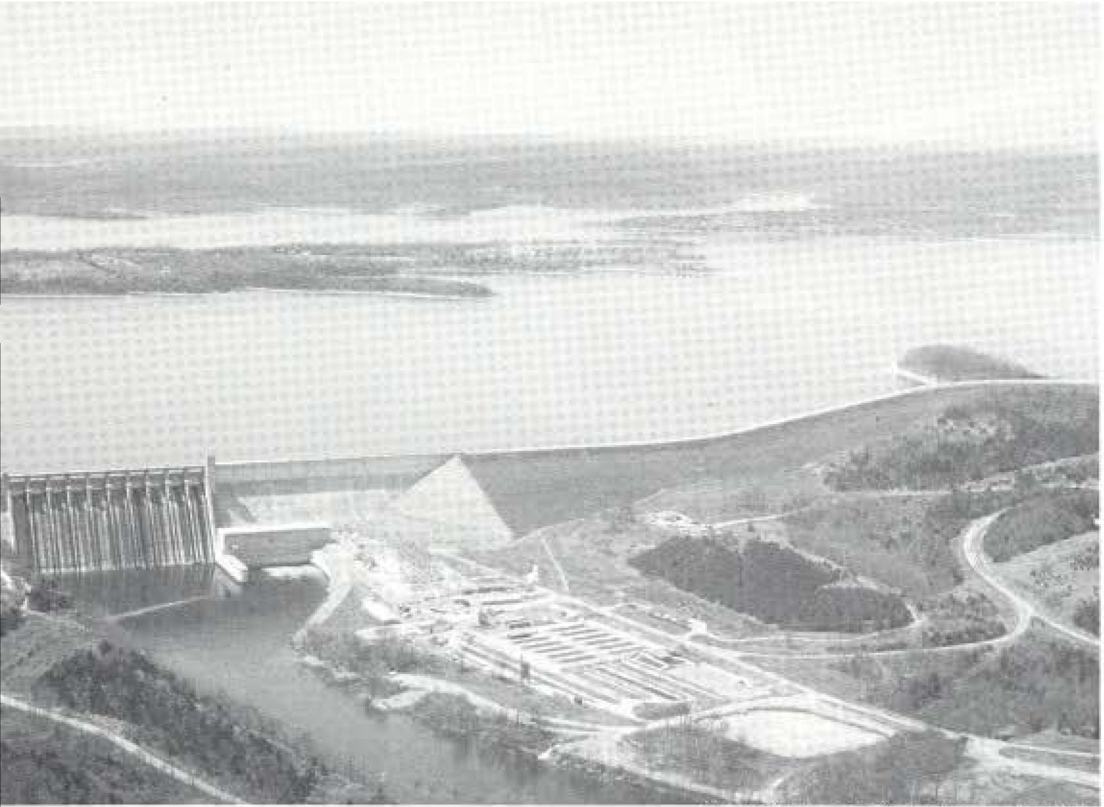
The first two large Missouri projects - the Powersite Dam, built by the Ozark Power and Water Company on the White River in 1913, and Union Electric's Bagnell Dam, completed on the Osage River in 1931 - fulfilled their builders' expectations in most respects, gave the dam-building process considerable validity, and prodded government agencies into action. In fact, although the two dams were principally designed to satisfy the rapidly expanding electrical needs of residential, industrial, and mining consumers, their long-range economic impact would prove far greater. The effect of these dams on regional land values, income, and development far outshone any power generation or flood control benefits. For better or for worse, one need only compare the Bagnell and Branson of today with the same areas 50 years ago. Lake Taneycomo (Taney County, Missouri), behind the Powersite Dam, and Lake of the Ozarks quickly became popular fishing, boating, and swimming resort areas.

The federal Comprehensive Flood Control Act of 1938 proposed the construction of 30 major dams in Missouri, including at least one on every Ozark River, with as many as six on the Current River alone. Ozark streams were not the only targets. The entire nation was caught up in a dam-building frenzy. Water projects popped up on the Pacific coast in the Sierras and Cascades, throughout the desert southwest and Texas, through the Rockies and out into the plains, across the Midwest, and over the Appalachians into the East, wherever influential congressmen saw jobs, money, and votes. Some schemes were truly grandiose. The Pick-Sloan Plan, for instance, authorized by congress in 1944, sought to achieve complete control over the entire Missouri River with 104 flood control and hydroelectric reservoirs, irrigation ditches, and a 9-foot navigation channel.

In Missouri, the next in line after Bagnell tamed the Osage was Lake Wappapello, completed on the St. Francis River in 1941. Five years after its completion, 4 feet of floodwater spilled over the dam, causing the worst flood in the history of the lower St. Francis. To absorb future floods, the Corps of Engineers was forced to allocate a greater difference between the normal low pool and high pool levels.

In 1945, construction began on Bull Shoals Dam, immediately

Table Rock Dam on the White River in Taney County.



Missouri Department of Natural Resources File Photo downstream from Lake Taneycomo. In the same year, congress set aside the first of hundreds of millions of dollars still to come for another, larger impoundment on the Osage River upstream from the Bagnell Dam. By then, the White River, already tethered by Taneycomo, was further tamed by the 1944 completion of the Norfork reservoir on a major tributary downstream. To the east, Clearwater Lake was completed on the Black River in 1948.

With the completion of Bull Shoals in 1951 and Table Rock in 1958, the White River essentially ceased to exist as a river habitat in Missouri. The lakes took with them the only known colonies of three rare Missouri plant species: the French mulberry, the wooly lip-fern, and a type of nettle. They also drowned significant numbers of other currently rare and endangered plants, including Alabama lipfern, cucumber magnolia, golden current, soapberry, and yellow wood, as well as some of the state's grandest stands of giant cane, all of which had occupied its former valley.

Farther north, three more dams, and the first large Missouri reservoirs in regions bordering the Ozarks - Pomme de Terre in 1961, Stockton in 1974, and Truman in 1983 - were completed on the Osage River system. Like Bagnell, Wappapello, and Table Rock before them, problems emerged as these new dams came on line. Due to a slight engineering miscalculation, for example, Stockton Dam was equipped with power generators far too large for the size of its river or its reservoir. Farmland downstream was flooded and acres of ground were washed away whenever the turbines were fully opened.

At Truman, full operation injected so much air into the downstream pool that fish got the bends, caused by an accumulation of air bubbles in their veins, and bellied up to the surface, dead. An expensive modification of the spillways solved this problem, but a pumpback system designed to run the Osage's waters back and forth through the dam proved to have another fatal flaw. Within minutes of the device's trial operation, its whirling blades chopped thousands of fish to shreds. All attempts to screen the intake and outlets proved ineffective and the pumpback feature remains inoperative. It is likely that only four of Truman's six turbines and generators can be used safely because of erosion and potential disturbance to fisheries and recreational boating downstream. Truman Lake also completely flooded the last and largest Missouri spawning sites of the paddlefish, a unique and ancient species whose continued existence in Missouri now depends largely on artificial propagation.

The damming process spread far outside the Ozarks and has continued into the 1990's. The Thomas Hill Reservoir backed up the Middle Fork of the Chariton River in 1966 to provide cooling water for a power plant, and in 1973, Smithville Lake was impounded on the Little Platte River north of Kansas City. Farther east, the Clarence Cannon Dam was completed on the Salt River in 1984, impounding Mark Twain Lake, the fifth largest reservoir in the state, and the largest in the state north of the Missouri River.

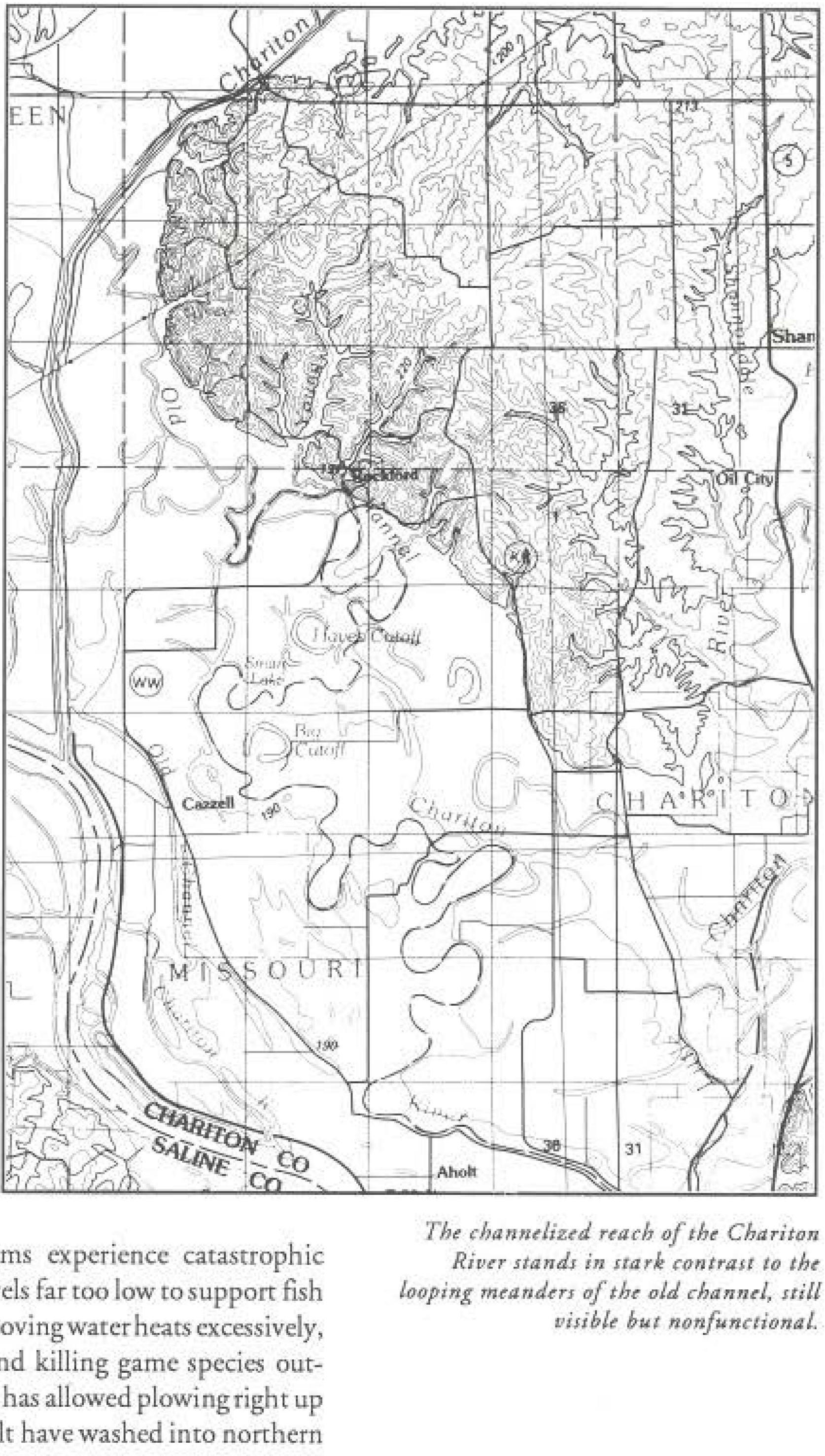
Speeding Missouri's Waters

At the same time that damming Ozark streams garnered intense interest and public attention, both pro and con, Missouri's other rivers were also being rapidly altered. Although they are not as beautiful nor as pristine as Ozark rivers, nor as productive as western prairie streams, the muddy rivers of northern Missouri actually support far more person-days of use each year. In 1970, for instance, the lethargic Platte River entertained up to 10 times as many people on any one summer day as there were visitors to the Current River. Nevertheless, the threats to northern streams have generally been of a different sort and have largely escaped public notice.

The lack of big dams in northern Missouri is the result of a combination of several factors. From an engineering standpoint, the broad, shallow valleys of the till plains are not as easily tackled as the deep, narrow ravines of the Ozarks. The gradients of these streams are generally too slight for power generation. The agricultural value of riverbank farmland is much greater than any Ozark bottomland. Consequently, flood control in the till plains has taken a totally different tack. Instead of holding back floodwaters, engineers have sought to drain the waters away more quickly.

Through colossal channelization projects, mile after mile of contorted prairie streambed has been drag-lined into oblivion. Including the Big Rivers, over 5,000 miles of Missouri waterways have been channelized, resulting in the loss of 2,500 miles of natural channel and

97 percent of the state's wetlands. Instead of vegetation-cloaked rivers that meander widely between old cut-offs, marshes, and sloughs, most northern streams now flow straight to the Missouri or Mississippi rivers through steep-banked muddy ditches. Channelization projects have altered reaches of all major northern Missouri streams, including the Tarkio, Platte, Nodaway, Grand, Chariton, Blackwater, Fabius, Wyaconda, and North rivers, and hundreds of their tributaries. Very few miles of unaltered streambed exist in a pre-settlement condition in northern Missouri. If the object of channelization was to get the water out of here and dump it on the guy downstream, it has certainly worked. Flooding has become much more intense along the lower stretches of these rivers and streams, and the Missouri and Mississippi farther along, now that the natural flood-containment basins - the broad systems of wetlands and backwaters alongside the main channels of these streams in their unaltered condition - have been drained, leveed, or filled. With the water-holding capacity of their natural wetlands destroyed, channelized streams experience catastrophic flushings after each rain, then drop to levels far too low to support fish during dry periods. The exposed, slow-moving water heats excessively, lowering its oxygen-holding capacity and killing game species outright. Because straightening the channel has allowed plowing right up to the stream bank, millions of tons of silt have washed into northern Missouri's channels, floodplains, reservoirs, and lakes during the past 50 years.



The channelized reach of the Chariton River stands in stark contrast to the looping meanders of the old channel, still visible but nonfunctional.

Channelization causes the loss of backwaters and side channels, and the river becomes unattractive to shorebirds and waterfowl. Populations of streamside mammals, such as beaver, muskrat, otter, and mink, decline significantly following such alterations and the numbers of fish may be reduced to 10 or 20 percent of original levels. The variety of fish species is often cut by half.

The Beginnings Of A Conservation Ethic

The 18th and 19th centuries in Missouri - and across North America - were times of frontier-style resource management. It was an era dominated by the "get-it-while-it's-still-there" approach to farming, hunting, fishing, mining, timbering, and other human endeavors. The Juggernaut of progress thundered across the landscape, extracting riches without any thought for the future. There was always more land to the West; another valley with better soil, more trees to be felled, an undiscovered lode of mineral wealth for the taking. In many ways and in many places - stream alteration, for instance - the 1900's has offered little more than a straightforward continuation of these frontier-style philosophies.

At the same time, however, the 20th century has been a period of slow, thoughtful change in resource use. There is no watershed time, date, or year by which we might age the birth of this new attitude toward the American landscape and its resources. Many American scientists who were trained in European universities during the 19th century came away with progressive ideas concerning soil conservation and recovery, resource development and utilization, and social progress. Many of these helped foster changes in attitudes at both the state and federal levels. Certainly some of the romantic philosophical ideals of the 18th century European enlightenment - the "noble savage" of Rousseau and the glorification of wilderness by Byron, Wordsworth, and Goethe, among others - were instrumental in charting a course for the conservation movement of the late 19th century. In the late 1800's the writings and ideals of these 18th century romanticists were responsible for the birth of a movement dedicated to the preservation of wilderness in all its beauty. They expressed a belief that wilderness had a cleansing effect on people sullied by the physical and psychological contamination of urban industrial life and capitalistic endeavors. A soul-renewing wilderness experience brought a person back to reality and brought to focus what was truly important in life. Nineteenth century romanticists became devout preservationists of wilderness and wild things, and founded a preservationist movement that is alive and strong today. Early in the 19th century the scientific approach recognized the need for resource utilization, but under wise stewardship. This non-preservationist approach, called resource conservation, required active control and management of natural resources if they were to continue to be available in the future. Working together at first, and intermittently since, the preservationists and conservationists, even with their somewhat disparate views of the world, were responsible for the blossoming of a conservation mentality during the second half of the 19th century and the early 20th century.

Public interest in soil, wildlife, wilderness, forests, minerals, air, water, and other resources awakened to differing degrees, at different times, and by different chains of events. The process was aided initially by the turn of the century decline and loss of the American frontier, recognized by all and mourned by many segments of the population at the time. It is now assisted by the arrival of the 21st century, for decades a distant turning point by which 20th century trends could be measured, but now here at last.

Could Nature's Bounty Continue To Feed America?

Perhaps from necessity the conservation movement arose in the field of agriculture and soil conservation in the 1830's and 40's. America had initially built its financial foundations on high agricultural output, but, in the East and South at least, her soils had become impoverished by overuse and were no longer productive. From soil, concern about America's dwindling resources may have spread to wildlife, forests, wilderness, and other areas; or each may have had its own completely independent beginnings. Regardless, soil was certainly one of the first American resources about which deep concern was expressed and for which positive action was taken.

Progress in the field of soil science was slow and successful only because of the active involvement of the federal government, beginning with Henry Ellsworth's one-man program of seed distribution out of the U.S. Patent Office in 1837. Three years later, Congress

Nick Decker

Soil erosion, identified as a major threat to Missouri agriculture, increases on steep, heavily-cultivated slopes, as shown here on a field in northern Missouri.

authorized $1,000 for his program, now baptized as the Agricultural Division of the Patent Office, which had expanded to include agricultural statistics and experimentation. With continued diversification, his program was transformed into an autonomous and far-reaching Department of Agriculture in 1862. During this same period, the federal government granted land to 20 states for the establishment and expansion of agricultural and mechanics colleges to help spread the word about soil husbandry and modern methods of agriculture.

Since 1840, most of "the word" had come from the pen of Justus von Liebig, a German chemist who proved that particular soil minerals, and not the humus itself, were necessary for proper plant growth. Liebig showed that these minerals, such as nitrogen, phosphorus, and calcium, were lost when crops were harvested and had to be replaced in order to maintain soil fertility. By 1843, guano was being shipped from Peru as a source of nitrogen and phosphorus. By 1860, the Mississippi State Geologist, Eugene Hilgard, who had grown up in Belleville, Illinois, had adopted the most scientific approach to soil chemical analysis and recommended manuring, fertilization, and contour plowing, adding that no land could be maintained indefinitely without proper husbandry practices and replacement of minerals. Moving west to Berkeley, he went on to found the first agricultural experiment station to combine both the theoretical and practical approaches.

Not until 1905 was the Missouri Soil Survey organized under the supervision of Dr. Curtis Fletcher Marbut, Professor of Geology at the University of Missouri. In 1909, Marbut moved on to serve as chief of the U.S. Department of Agriculture's Division of Soil Survey. Always maintaining close ties with Missouri, Marbut became a guiding light of American soil science, developing the first nationwide map of soil groups and spurring national interest in soil conservation. Thus Missouri has a relatively long history of soil research and a huge backlog of scientific data, even though detailed, systematic soil surveys of Missouri counties did not commence until the Depression-Dust Bowl years of the mid-1930's.

The End Of Market Hunting

As early as the 1850's, a few astute people had become alarmed at the wildlife situation in Missouri and had begun a series of moves that would at once improve the situation and confound it. The first Missouri wildlife law was passed in St. Louis County in 1851 and was intended to control the periods during which game might be sold. Informed residents had come to realize that uncontrolled, year-round market hunting was the leading cause of wildlife loss in their region. In 1857, another game law was passed for Pike and Lincoln counties, but lasted only two years. A third, passed by the state legislature in 1861, protected streams throughout the state from obstruction by dams, seines, or nets. Three years later, 17 species of insect-eating songbirds received a measure of protection from a St. Louis County law intended to save orchards from damaging insects. A second statewide game law was passed in 1874 imposing closed seasons and banning the sale of wild game out of season. Despite these measures the situation continued to deteriorate. Early laws were not only mostly local, they seldom came with real teeth. They often went unfunded and unenforced, and were generally ignored.

Despite growing opposition from an increasing number of sportmen's organizations, as well as preservationist groups, such as the fledgling Audubon Society, founded originally as the New York Audubon Society in 1886, market hunting continued with little abatement. In 1895, the state established an office of Fish and Game Warden, but allocated next to nothing for its operations. The same level of lip service was in evidence when, in 1901, the legislature passed another law forbidding exports of game from the state, again giving no financial support. The legislature then abolished the fish and game office entirely in 1903. The stroke that finally created a critical level of opposition to market hunting was the nearly 4,000,000 pounds (Yes, 2,000 tons!) of wild game sold in Missouri during the year of the Louisiana Bicentennial Exposition, known more commonly as the 1904 St. Louis World's Fair, and at the fair itself. By then the last passenger pigeon had been killed in the state and virtually all other valuable wildlife had vanished. All of the game sold in Missouri in 1904 was in violation of state law, but not a single person was prosecuted.

In 1905, the enormity of the situation spurred passage of a new act which became known as the Walmsley Law. Walmsley put it quite simply; all wildlife was the property of the state. According to this act, non-game animals would be protected, quotas and seasons would be managed by a new Department of Game, and market hunting was outlawed altogether. Strict enforcement was built into the law with allocations, from the sale of licenses, to pay meaningful salaries and expenses for game wardens. Although the original law was subsequently weakened and had its teeth pulled by a number of revisions pushed through the legislature by hostile commercial and political interests, its basic premises were rewritten and reaffirmed in 1909. For the next few decades this revision of the Walmsley law managed to hold out against frequent attacks and, although more or less ignored and emasculated by subsequent sessions of the Missouri legislature, was the law of the land until 1936.

At the national level, conservationists realized that state-by-state action would not be sufficient to protect migratory birds, which do not recognize political boundaries. In 1903, in response to the slaughter of birds for feathers to supply the millinery trade, President Theodore Roosevelt created the first National Wildlife Refuge to protect herons, egrets, and pelicans. Expanding protection to ducks and geese, a federal Migratory Bird Act was passed in 1913. Agreements dividing responsibilities and quotas with Canada were reached several years later. These actions eventually led to the development of a huge system of federal wildlife refuges that now totals over 90 million acres and, in 1940, to the establishment of the U.S. Fish and Wildlife Service. Originally organized to manage wildlife, especially migratory waterfowl and other huntable species, the Fish and Wildlife Service has deepened its commitment to nongame species, particularly those that are rare and endangered (including plants), as well as to biodiversity, that is, to the maintenance of whole ecological systems.

The closing decades of the 19th century also saw the creation of America's first national parks. In the frontier outlook of the late 1800's, places such as Yellowstone, Yosemite, Mount Rainier, and Glacier could not have been declared national parks simply on their own merits, regardless of public demand or the rationality of the conservationists and scientists backing the movement. Congress was adamant about natural resource development and would not set aside

Nick Decker

Bison grazing in Prairie State Park evoke memories of the great herds that once roamed free across the seemingly endless grasslands.

any land as park that might have any other kind of resource value. Only when the railroads lobbied heavily, noting that these areas could be developed for mass tourism, did legislation proceed. For a time the U.S. Army patrolled new park lands to suppress market hunting and poaching, but in 1916 an act was passed transferring management of national parks to a new National Park Service. By 1917, 16 national parks and 18 national monuments had been set aside.

Meanwhile, back in Missouri, a similar movement for establishment of park lands was afoot, especially since no areas of national interest had been identified in the state. In 1917 a law was passed requiring that five percent of Missouri's hunting and fishing license fees be spent for the purchase and maintenance of Missouri's first state park lands. A number of state parks and forest preserves were created, although most were not fully developed until the period of the Great Depression. One upshot of this 1917 law, which was viewed by sportsmen as an unfair expenditure of wildlife funds, was that, when the Missouri Conservation Commission was established in 1936, state parks would be intentionally excluded from the new conservation department's list of responsibilities.

In the meantime the wildlife situation continued to deteriorate. In an attempt to re-establish huntable wildlife populations, most other states had already begun restocking native species or stocking introduced species from other parts of the world. Missouri now followed suit. A rapid proliferation of fish hatcheries, game farms, and stock-and-release programs followed. Discouragingly, most releases met with failure. If they were not shot or caught right away, the animals simply disappeared.

A Fresh Approach

Between 1931 and 1935 the Walmsley Law was weakened still further, provoking resentment in the wildlife, timber, preservation, and conservation communities, including a number of sportsmen's organizations, such as the Missouri Duck Hunters Association and the Izaak Walton League. The spark of anger soon ignited a conservation revolution. A conglomeration of these conservation groups, calling themselves the Conservation Federation, eventually joined such diverse groups as garden clubs, bird-watchers, and boy scouts to propose a new constitutional amendment, Amendment No. 4, which would appear as Proposition No. 4 on the 1936 presidential ballot. This amendment, which passed overwhelmingly, created an autonomous Missouri Conservation Commission.

The bipartisan Conservation Commission was intended to manage Missouri's wildlife resources. Comprised of four gubernatorial appointees, the commission was empowered with the authority for the *"control, management, restoration, conservation, and regulation of the bird, fish, game, forestry, and all wildlife resources of the state."* The commission's primary task was to define the general goals and philosophies of a new Missouri Department of Conservation which would then carry out the slow process of restoring Missouri's renewable fish, game, and forest resources. Through research, cooperation with private landowners, education, propagation, and enforcement, the restoration process would now move ahead.

State parks, on the other hand, would be managed by a separate State Park Board. Much later, in 1974, state parks were brought under the administrative control of a Division of Parks and Recreation within a new Missouri Department of Natural Resources.

Many states give bureaucratic recognition of wildlife as natural resources by including them within their various departments of natural resources. The history of wildlife and other natural resource management in Missouri has had the strange effect of creating separate bureaucracies to manage the state's resources. The Department of Conservation manages wildlife and forests; the Department of Natural Resources manages air, water, soil, geology, parks, and historic sites. The obvious (at times) duplication of effort, staffing, and funding of Missouri's dual natural resource management departments might seem wasteful at first glance, but has actually been good for the state and its resources. Both the preservationist and the conservationist points of view have a voice at the state management level.

By 1980, of the 44,598,976 acres granted Missouri at statehood in 1821, 3,000,000 acres had been paved over or built on, 15,000,000 had been plowed, 13,000,000 provided grazing, 150,000 had been mined, and 700,000 were permanently flooded. Of the 12,500,000 acres remaining, most was held in private ownership and was unavailable to the average citizen. Clearly public ownership of land was going to play an increasingly vital role in the decades to come.

Regenerating Forests - Regenerating Habitat

While America's wildlife was overhunted in the first centuries after settlement, in some cases to extinction, her forests were also reeling under the impact of unmanaged harvesting. By 1850 the lumber industry, centered in Maine during the first half of the 19th century, was forced by lack of timber to move first into western New York, then south into Pennsylvania, and westward around the Great Lakes. By the 1880's the virgin yellow pine forests of the South were cut and great stands of western redwoods and Douglas fir were already being felled. The Ozarks were not spared during the westward migration of sawyers. By the end of the 19th century, following the development of Missouri's railroad system, nearly all of the state's original forests had been cut. The last tracts of any appreciable size fell by 1920.

The "cut-out-and-get-out" approach of the timber industry triggered a rising groundswell of support for some sort of control over the nation's forest resources. In 1873, the American Association for

Susan Dunn

Forest management was slow in coming to the Missouri landscape, but it shows great promise for restoring some of the magnificence of pre-settlement forests.

the Advancement of Science began lobbying for legislation to control cutting. Soon thereafter, in 1875, Congress created a Division of Forestry under the Commissioner of Agriculture. A year later the American Forestry Association was founded. As these events at the national level gained momentum, they had a beneficial effect at the state level. From New York west many states began setting aside uncut or recently regenerated land as forest reserves. Between 1891 and 1892, Benjamin Harrison, influenced by a new breed, scientific foresters trained in Europe, set aside 16 million acres as federal forest reservations. After 1905, these became the core of a national forest system managed by the new United States Forest Service under the direction of Gifford Pinchot. Strongly supported by Teddy Roosevelt, Pinchot's chief management philosophy is best summarized by the phrase "multiple-use," which, at the time, incorporated grazing rights and watershed management into timber management, but neither esthetic nor wildlife habitat concerns.

Stimulated in part by keen railroad interest in a steady supply of ties, widespread planting of trees began in the early 1900's, even though local groups had become interested in planting trees years earlier. In Nebraska, for example, the nation's first Arbor Day had been celebrated in 1874. Unfortunately, railroad companies tended to plant fast-growing species, such as catalpa and black locust, which seldom produced usable saw logs. However, some railroads also gave saplings to any cooperative landowner along their rights-of-way who would plant and nurture them, stimulating interest in trees and forests. Many of these trees are still visible along old rights-of-way and around older farms. With the encouragement of the railroads and timber interests, a course in forestry was begun at the University of Missouri in 1911. However, with little high level state support, the forestry course came to a temporary halt after ten years. Later, in 1925, the General Assembly created the office of State Forester within its Department of Agriculture. Unfortunately, since the legislature had only provided funding for the operations of a single man in the field, results were slow and very limited. The legislature killed the abortive effort in 1931.

Wildlife and Habitat - The Ties

By the early 1930's, most Ozark wildlife had vanished as a combined result of habitat loss and unrestricted hunting. The original Ozark forest was all gone. Attempts to reintroduce wildlife failed miserably. Clearly, wildlife would not respond until suitable habitat was available once again, with or without the minimal level of control over hunting provided by the Walmsley law. The University of Missouri began its first wildlife management course in 1931 and, in a moment of enlightenment that would seem obvious to most people today, the Commissioner of Game listed the food, cover, and protection offered by forests as necessary to the recovery of wildlife populations. Still, in the decade between 1936 and 1946, the only financial support granted to the state's forests was a small percentage of the new Conservation Commission funds.

If significant gains were to be made in forest restoration, it would be necessary to control access to the land and to its timber resources. Even more important was the need to educate users and landowners in the basic principles of forestry and wildlife management. Although control over large tracts was achieved rather abruptly by purchasing or repossessing large areas of land for state and national forest during the depression years of the mid-1930s, the acquisition and dissemination of knowledge would prove to be a slower and more difficult task. The semi-isolation of the Ozark population was still a factor in the 1930's, and continues at some levels even today.

State and federal purchase of forest land generally required removing people from the area. The resulting reduction in population had the immediate beneficial effect of limiting the over-harvesting of resources. Many of the displaced had continued to hunt game for food, regardless of species, age, sex, or season, and to perpetually cut even very immature, barely recovered trees in order to subsist. With the removal of these independent souls, bent on scratching a living from the despoiled land, the forest could now regrow. Of the private landowners who remained, most generally retained possession of cleared valleys and ridgelands along major roads. While this created a complicated mosaic of private, state, and federal ownership within the forest, it also aided in the dispersal of new ideas. The proximity of private land to areas under direct management allowed the slow, indirect absorption of forestry techniques. By their example, foresters slowly managed to reverse practices that had gone unchallenged and unchanged for generations. Foremost among these was the regular burning of the woods.

Fire control remained a major problem that would require decades of hard work, education, and cultural change. Most politicians and landowners were reluctant to recognize the scope of the forest fire problem and its trickle-down effects on timber value, soils, and wildlife. In state and national forests, the task of fire suppression was simplified by the mere fact of public ownership. On public lands, the job consisted largely of detection and control by a few trained personnel. However, most Conservation Commission employees had a much tougher job. Since the largest percentage of lands the state foresters dealt with were private, the agents were forced to confront property owners - patiently, politely, and subtly - stubbornly clinging to the old ways.

An example: For 30 years wildfires burned in the Ava District an average of one a day, two days out of every three during good years, and two a day every single day in bad years. Spring was the worst season, the time when tradition dictated that the woods be fired. Another spurt of incendiary activity came in late autumn when everything was tinder dry and newly fallen leaves caught fire easily. After decades of intense educational effort and persistent fire-fighting, that number was finally reduced to an average of only two fires a month. In part, forest fire control was slow in coming because no funds for forestry or fire-fighting were actually allocated from general revenues by the state legislature until 1946. Once that one remaining obstacle was overcome, successes came more quickly. By 1950, over six million acres were guarded by ten fire protection districts, and the

Nick Decker

A controlled burn at Ha Ha Tonka State Park demonstrates the beneficial role of fire in revitalizing and maintaining savanna landscapes.

total area damaged by fires had been slashed to less than one percent of the territory patrolled.

Ironically, fire is now recognized as a valuable management tool. Fire is necessary to the revitalization and maintenance of certain types of communities, such as prairies, glades, and savannas. For thousands of years, the creatures of these communities have evolved in close association with fire and its effects. Without fire, many are quickly lost. However, timing and weather conditions are extremely critical in achieving the desired level of control. Too late in the year or too windy, and valuable plants may be damaged. Too early or too wet, and unwanted species will survive. Research continues as managers and ecologists explore the value and mechanics of this powerful weapon that has always been a natural community-altering and community-creating force, but which for so long had fallen from grace because of misuse and overuse. Many of our state parks, including Ha Ha Tonka, Prairie, Cuivre River, Pershing, and Hawn, offer visitors insight into the beneficial use of fire as a management tool.

To complete the process of forest healing, wildfire control would have to be accompanied by the demise of another old Ozark tradition; the open-range grazing of livestock. For more than 150 years, cattle, sheep, goats, mules, burros, and horses had browsed and grazed through the woods, stripping flowers, fruits, seeds, leaves, twigs, and bark from the ground up as high as they could reach. Free-roaming hogs took care of everything below ground level, plowing widely

Susan Dunn

For nearly 40 years, for no more than the extremely low price of production, private individuals have purchased millions of tree and shrub seedlings for beautification, erosion control, Christmas tree production, and wildlife food and cover, from the Department of Conservation's nursery at Licking.

through the countryside and literally leaving no stone unturned as they nosed for insects, bulbs, and roots. Subsistence-level stock owners had needed the open-range system to provide adequate forage on the sub-marginal grazing land of the Ozarks. With open range they could also avoid having to buy and maintain expensive fencing. Although local stock confinement laws had been enacted as early as 1890, the destructive practice was not outlawed entirely until 1965.

The widespread planting of trees by farmers and other private individuals, especially in areas outside the Ozarks, helped to speed the recuperation of Missouri forest and wildlife populations. In 1939, to encourage the establishment of windbreaks and woodlots, to provide farmers with a supply of fence posts, and to help control erosion, the U.S. Forest Service began distributing seedlings to the public at cost. From their nursery at Licking, the national foresters shipped out over a million ash, pine, black locust, red cedar, and black walnut each year. Curtailed during the second World War, the tree farming operation was taken over by the Conservation Commission in 1947 and has been in continuous operation ever since. For nearly 40 years, for no more than the extremely low price of production, private individuals have purchased millions of tree and shrub seedlings for beautification, erosion control, Christmas tree production, and wildlife food and cover.

Private individuals and corporations currently control 14 million acres or 90 percent of Missouri's forest lands. Consequently, involving private landowners in forestry programs was essential to the full recovery of the state's forest habitats. In 1946, to encourage private landowners to let their stands of forest mature, thus improving both their market and wildlife value, a far-reaching revision was made in Missouri property tax laws. Upon application of the owner, tracts of 40 acres or more could be labeled "Forest Cropland" by the Conservation Commission. For a period of 25 years, the owner's property taxes dropped to $1 per acre. The state would make up the difference with the tax yield when the timber was finally harvested. In each of the 25 years, the state reimbursed the county at the rate of 2¢ per acre to help replace the income lost by the deferred tax. The Forest Cropland system proved popular, especially among urban-dwelling landowners who purchased Ozark land chiefly for its recreational value. The system has been highly successful in slowing forest deterioration and accelerating recovery throughout the Ozarks.

With the establishment of academic forestry programs, including one at the University of Missouri in 1947, intensive research began to reveal the secrets of success in managing Ozark forests. As a consequence, forest management became much more scientific. On public land, these approaches centered on a standard operating guideline, the multiple use-sustained yield principle, based on a slight modification of Gifford Pinchot's original management philosophy.

In order to achieve continual production, timber crops are harvested in different ways. From the more fertile and well-watered sites of state and national forests, larger, straighter trees are cut for use as posts, ties, flooring, pallets, stave bolts, and a limited quantity of dimensional lumber (2x4's, etc.). Rocky hills and ridges that support slow-growing, stunted stands are maintained intact to protect vital watersheds and, in a change from Pinchot's time, for recreation or aesthetic purposes. Storm or fire-damaged trees are often sold on the stump to commercial firewood cutters or allocated to the general public, who also have access to firewood from the national forests. Open, grassy glades are managed for grazing, recreation, and watershed protection. Some areas are designated as wilderness, with access and use strictly controlled to preserve their wild character.

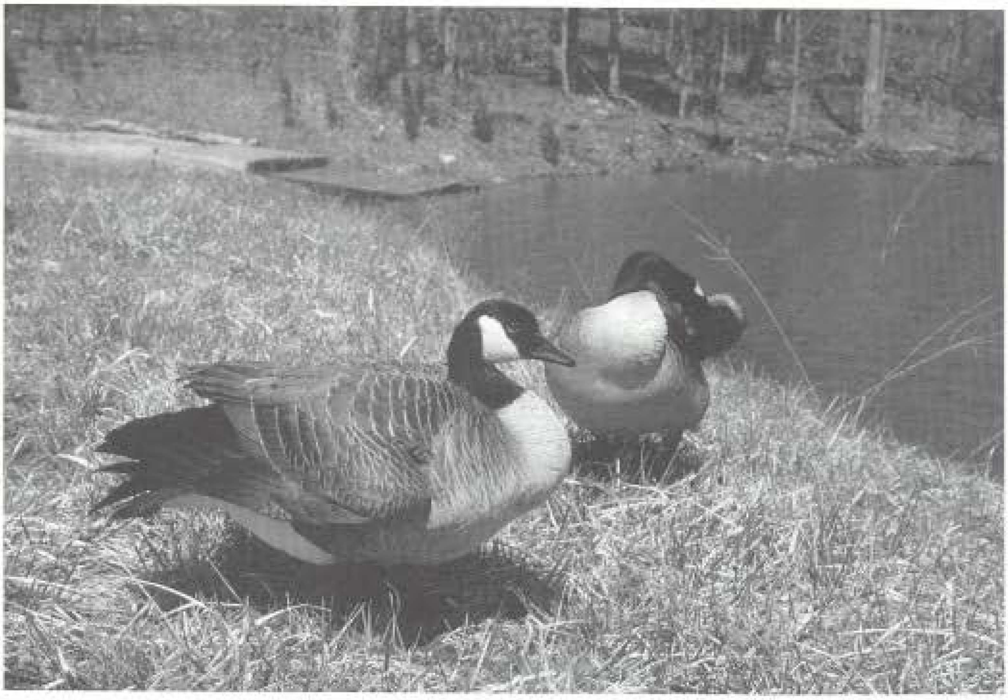
As the 20th century draws to a close, Missouri's recovering forests have received a helpful boost from a most unlikely source - the changing diet of the American public. While keeping tabs on their cholesterol and saturated fat levels, people have tended to buy less pork and beef, reducing the demand for and production of these red meats. This has contributed to a decline in the need for marginal Ozark pasture. In the brief period between 1972 and 1989, forest surveys have noted an 8 percent increase in Missouri's timberland, at least some of which is attributable to the changing market basket. Coupled with almost two decades of additional growth in the size of the state's standing trees, this has helped increase Missouri's volume of available timber from 6.9 to 9 billion cubic feet. This growth - normal when trees are not cut too soon or too frequently - raised the number of Missouri's sawtimber trees by 25 percent.

The Farm Pond Program

All of these approaches to forest management demonstrated a growing recognition of the needs of wildlife for food and cover, and all generally improved conditions for game populations. Nonetheless, there was still one major ingredient missing from the recipe that might have hindered the ultimate success of the whole program - water. Following the "dust bowl" droughts of the mid-30's, the problem of limited water, especially along Ozark ridgetops in summer, was largely solved by the development of a farm pond program. The Conservation Commission, perhaps a trifle over-optimistically, bought a few horse- and tractor-drawn earth-movers to loan individuals or groups willing to build ten or more ponds in any one particular area. Perhaps predictably, the initial attempts were less than encouraging. As anyone knows who has wielded a shovel on an Ozark ridge, digging Ozark "soil" is nearly impossible, especially in light of the commission's guidelines. Each pond was to be at least 8 feet deep, fenced to prevent erosion damage by cattle, and have a pipe laid through the dam to supply a watering trough below. The difficulty and expense of the time-consuming task quickly discouraged the few interested farmers and landowners. The department's offer of earth-moving equipment found few takers.

One result of nearly a century of dam-building and pond-digging is that Missouri, with practically no natural lakes to call its own, now ranks among the top five states in artificial impoundments, with over 500,000 acres of trapped water. This distinction is brought home most convincingly when flying over the state into a rising or setting sun. The glint of a hundred suns far below recount the number of waters captured, large and small.

The combined result of the many different approaches to habitat restoration and improvement, and of the varied wildlife conservation tactics have paid off. Turkey, Canada geese, and deer now wander into suburban backyards, where they are sometimes greeted as pests instead of reminders of a tremendously successful recovery program. Indeed, while turkey and goose scats on the patio can be distressful to those familiar only with sparrow droppings, deer are known to pillage expensive landscaping. While only a few places in Missouri have yet experienced such depredation, homeowners in eastern states are accustomed to erecting tall burlap shields to fend off hungry browsers. Another Missouri plant-eater, the beaver, has recovered so well in the absence of a market for beaver hats that limited control programs have been instituted in some places to protect streamside vegetation. With continued assistance from wildlife officials in outstate areas, ruffed grouse, bald eagle, trumpeter swan, river otter, and prairie chicken populations may one day return to levels reminiscent of past centuries.


Ralph Hess

Canada geese find rest and food beside a Missouri farm pond, one of several hundred thousand that dot the landscape.

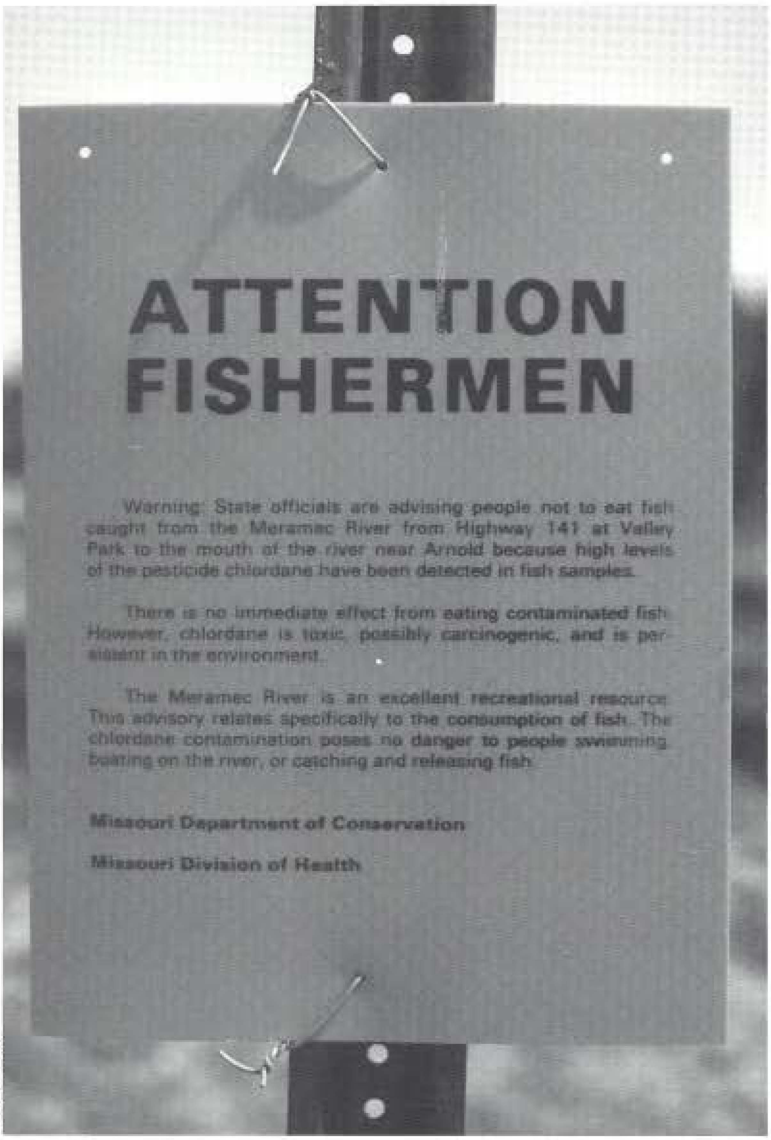
Keeping Some Rivers Free

As the 20th century progressed, Missouri's population became increasingly urban. With the advent of the automobile, the five-day work week, and generally prosperous times, the state's wild resources gained increased attention for their recreational value. The progress of forest and wildlife recovery programs enticed more and more hunters, campers, and hikers into the Ozarks. Among the diversity of outdoor experiences available in Missouri, the Ozark float trip surely ranks near the top. Floating Ozark streams was initially only a means of transportation or a way to gather wild foods and furs for those who pioneered and lived in the region. After the turn of the century, however, the float became a truly popular recreational activity for non-Ozark natives as well.

Other Aquatic Assaults

The federal Water Pollution Control Acts of 1956 and 1972 mandated that all streams and rivers be returned to conditions suitable for swimming, boating, and fishing by 1985. The acts provided funds for sewage treatment facilities and were instrumental in slowing the decline of the nation's waterways. Even as recently as 1958, for instance, no Missouri towns or industries were treating sewage before dumping it into the Missouri River. After the various clean water acts were passed, industries, food processors, cities, and towns were all required to install sewage treatment facilities to forestall the discharge of wastes into streams and lakes. Under heavy pressure and close scrutiny, more than three decades of control have brought measurable improvement. Ordinary sewage pollutants are down; fish and recreation are up.

Planners are now adopting tried and true natural mechanisms in the fight against sewage, billion-year-old techniques that have been used by Mother Nature ever since the first aquatic organisms polluted their own bodies of water. Natural cycles of decomposition convert wastes into vital nutrients that enhance the growth of vegetation. The resulting growth provides food for plant eaters, who in turn feed various kinds of predators.



ATTENTION
FISHERMEN

Warning: State officials are advising people not to eat fish caught from the Meramec River from Highway 141 at Valley Park to the mouth of the river near Arnold because high levels of the pesticide chlordane have been detected in fish samples.

There is no immediate effect from eating contaminated fish. However, chlordane is toxic, possibly carcinogenic, and is persistent in the environment.

The Meramec River is an excellent recreational resource. This advisory relates specifically to the consumption of fish. The chlordane contamination poses no danger to people swimming, boating on the river, or catching and releasing fish.

Missouri Department of Conservation

Missouri Division of Health

Jon Hawker

One unwelcome addition to the Missouri landscape is this sign warning of pesticide contamination in fish.

Contaminants And Contamination

After the Second World War, the growth of the chemicals and plastics industries created thousands of new organic compounds never before encountered by the decomposing bacteria of our streams and rivers. Chlorinated hydrocarbons, that is, petroleum-based chemicals carrying the deadly element chlorine in one form or another, were among the most common and diverse. A large number of these compounds fell into various classes of agents designed primarily to kill things. Among these were insecticides, such as DDT, heptachlor, dieldrin, aldrin, hexachlor, endrin, and chlordane; disinfectants, like hexachlorophene; wood preservatives and fungicides, such as pentachlorophenol, marketed as Penta; and herbicides, like 2,4-D and 2,4,5-T (the combination of which was used as Agent Orange during the Vietnam conflict). Others, such as carbon tetrachloride and chloroform, were used as solvents; as dry cleaning agents, like trichloroethylene and tetrachloroethylene; or in the processing or production of plastics and any number of other materials, such as methylene chloride and methyl chloride. A few chlorinated hydrocarbons, or organochlorines as they are also known, were produced solely because of some special property they possessed. Among these unique compounds were the liquid or semi-solid polychlorobiphenyls, better known as PCB's, which have tremendous stability and were used widely in electrical transformers and capacitors.

Viewed as the salvation of mankind when first introduced, pesticides such as DDT were supposed to rid the world of insect pests and help eradicate insect-borne diseases, such as encephalitis, malaria, and yellow fever. Unfortunately, some pesticides seemed to stop killing pests once the bugs became adapted to the new chemical, a natural evolutionary process called **resistance** that requires only a few years of genetic change. In addition, many of the new pesticides were found to cause serious health problems. Most unsettling, however, chlorinated hydrocarbons just seemed never to go away. Unlike ordinary household sewage, which if given exposure to air, sun, and bacteria, will be broken down in short order, most chlorinated hydrocarbons took a very long time to decompose. Because they were new to decomposing bacteria, many organochlorines required very long periods of exposure, sometimes as long as 50 years or more, before they were degraded. This persistence of chlorinated hydrocarbons in the landscape - a trait they share with heavy metals and radioactive wastes - quickly led to widespread problems for wildlife and fisheries.

Shortly after their introduction, excessive pesticide use was threatening animal life all across the state. In response to a fire ant scare in 1958, and to an army worm threat in 1964, for instance, enormous amounts of chlorinated hydrocarbons were sprayed in the Bootheel. Initially, pesticides were handled rather blithely, as if they killed only insects and no one need worry about themselves, other people, or wildlife. If a little pesticide was good, a lot was even better. They were after all, pesticides, and pesticides killed pests. Leftover spray and empty containers were dumped indiscriminantly and residues from over-sprayed fields quickly ran off into waterways.

Irresponsible disposal of waste materials results in contamination of streams and death to wildlife.

Gary St. Ivany

The Hidden Contamination

As the nation came to grips with its obvious water pollution problems, other hidden sources of danger began to appear. It had long been thought that the passage of water from the surface to its underground reservoir, the water table where ground water accumulates, cleansed and purified the water, making it safe to drink. This was the logic behind the outhouse and the septic tank. As the water and its wastes trickled slowly downward, bacteria decomposed the waste and converted it to less noxious forms. In the latter half of the 20th century it became clear that this notion was sadly and, in some cases, totally incorrect.

Just as surface cleansing systems can be overloaded by too much waste, so also can underground systems. Underground systems are naturally more sensitive, however, because of their inherently limited capacity for decomposition. Under normal circumstances, soil bacteria might easily degrade a small flow of raw sewage that comes their way. However, a large flow quickly depletes the oxygen supply and stifles the activities of the microscopic sewage-eaters. And, unfortunately, as their concentrations grow, the chemical materials released by the breakdown of sewage - nitrates, phosphates, and sulfates - are not much healthier in well-water than the sewage itself. This is why our expanding urban populations are necessarily followed by a network of sewage lines. In the absence of any kind of effective recycling system, we must treat our waste in the most efficient manner, centrally, then flush the byproducts downstream. And while we just barely manage our own domestic sewage, wastes from feed lots, hog pens, poultry houses, and dairy barns also threaten to get out of hand. Recycling manures as fertilizer and soil conditioner offers a useful solution to an otherwise perplexing and growing problem.

Missouri's Ozark geology presents another problem for wastewater managers. A review of the geological history presented earlier in this book will show that the region is underlain by massive layers of ancient carbonate rocks, now thoroughly laced by an interconnecting

Jon Hawker

Nutrients from human sewage, animal wastes, or fertilizers will promote the growth of algae, such as this colorful "bloom" in a park lake.

system of cracks, crevices, and caves. In many places, surface waters and soils do not allow rainwater and sewage to percolate slowly down into the bedrock, allowing adequate time for decomposition; instead they flush with each rain like giant, natural toilet bowls. Substances released on the surface appear in the subsurface within minutes, hours, or days, completely unaltered. Septic tanks and cesspools are not reliable treatment mechanisms where subsurface geology is like Swiss cheese.

The introduction of persistent chemicals into the underground system along with normal sewage severely overloads the bacteria of decomposition. It has been estimated that these microorganisms can destroy only about one percent of the toxic compounds that pass by; the rest accumulate in the groundwater. Heavy metals and radioactive wastes, such as those from the Weldon Spring site, are not broken down by bacteria at all. All persistent materials typically spread outward from the source along hidden channels, contaminating ground waters for miles in all directions. From manufacturing and dumping sites, from landfills, and from from leaks and spills, hundreds of different toxic and polluting agents have been seeping into our subsurface waterways for decades. Once we began looking for toxic chemicals deep in the Earth, the compounds began to be found everywhere.

Almost all Missouri sewage now receives extensive treatment before flowing into streams.

Jon Hawker

From New Jersey to California, ground water contamination has become one of the most serious environmental threats the country has ever faced. Wells have been found to be contaminated in every state in the union. Over half the people in the United States pump their drinking water from underground and large quantities are used for irrigation. The cycling of water from beneath the surface to agricultural, manufacturing, and domestic users, then back underground, delivers huge amounts of toxic residues to a pool that is unreachable and largely untreatable. If the chemicals are persistent, they may contaminate a water supply for decades.

Groundwater contamination has occurred all across Missouri wherever surface sources of toxic materials and porous rock layers have met. The state's problems have been well-publicized with local, sometimes spectacular incidences, such as those at West Plains, in Howell County, in 1964 and 1966, and at Republic, in Greene County, in 1968, where sewage lagoons suddenly collapsed into hidden cave systems, sending their contents directly into the groundwater supply and contaminating water supplies for miles around. A later incident, at Maramec Spring, also received considerable press coverage because it endangered rare species of cave animals. Unfortunately, groundwater contamination is generally too insidious and intractable a problem to warrant media attention and, unless personally involved, most people are unaware of the extent of the problem or simply turn their heads.

Fresh Air Gone Sour

Maintaining fresh air has been a problem ever since people began settling in cities. Whenever hundreds of families cook dinners and warm themselves over fires, periodic episodes of air pollution are sure to follow. There were undoubtedly times in the ancient city of Cahokia when wood smoke from a thousand fires hovered in the still winter air and a visitor would have gasped for breath and rubbed her or his teary, irritated eyes. Such occurrences would have been fairly rare, however, because the normal circulation of the atmosphere tends to carry off and dispose of air pollutants, much as waterways recycle theirs. The solution to air pollution is also dilution.

The first reports of air pollution in the young city of St. Louis appear in the early 1820's. While rural areas around the new state still relied on wood for fuel, many residents of the city were converting to soft coal from the nearby mines of southern Illinois. Firewood was becoming less convenient and more expensive; coal yielded more heat per pound of fuel, burned for a longer period of time, and therefore required a smaller storage area. Coal was also the fuel of choice for the high temperature brick ovens that sprang up south of the city. In 1824 the Board of Aldermen passed an ordinance forbidding the operation of brick furnaces within the city limits, but the rising cost of bricks that resulted, and an increased public acceptance of smoky air, soon forced the city fathers to back down from their initially firm stance. The city and its air pollution problems grew together through the rest of the 19th century and into the 20th century. There were times when the smoke was so thick that candles were needed at midday. St. Louis was widely regarded as the dirtiest place in the Mississippi Valley.

In 1893 a smoke abatement ordinance was passed that had some limited beneficial effect, but the law was found unconstitutional four years later. St. Louis' mayor pushed through another law, in 1898, that declared the city's dense smoke a public nuisance and established the office of Chief Smoke Inspector, empowered to issue fines of up to $25. This ordinance was expanded in 1902 to include steamboats moored at the levee and to require that businesses install equipment which would curb emissions. Even though the new ordinances eliminated an estimated 70 percent of the noxious fumes, damage to the urban environment remained heavy. Buildings were coated with foul, black soot; sulfuric acid formed from the high quantities of sulfur dioxide in the smoke etched stone and metal; books deteriorated in the public library; trees died everywhere. A study conducted in the early 1920's found that the average St. Louis resident inhaled 28 pounds of soot each year.

The replacement of horses and steam engines with gasoline, diesel, and jet engines changed the kinds of pollutants discharged into the urban environment. The mountains of manure and acrid smoke typical of 19th and early 20th century St. Louis were replaced by the carbon monoxide, sulfur dioxide, nitrogen oxides, ozone, and unburnt fuel of our modern transportation network. The increase in coal-fired power plants as the country was completely electrified, as well as other coal-burning industries, also contributed greatly to the sulfur dioxide and nitrogen oxides, as well as air-borne particles, or particulates. Various reactions among these noxious ingredients, in the presence of sunlight, produce the familiar brownish haze scientists call photochemical smog.

As our automobiles and trucks zip (or creep) from place to place, the process of combustion combines petroleum products with oxygen to release the solar energy stored in the fuel millions of years ago. Ideally, the by-products of combustion should be nothing but carbon dioxide and water, which result whenever we burn any organic material. Virtually all fossil fuels, however, including natural gas, coal, and petroleum, contain at least some sulfur, originally contained in the proteins of the plants and animals that became fossilized. Combustion converts these "fossil proteins" to sulfur dioxide. This accounts for the "burning match" smell vented into your car from the one in front as it accelerates away from a stoplight. The same thing happens in oil-fired or coal-fired power plants, trains, buses, and airplanes.

At the tremendously high temperatures in the cylinders of a typical engine, and in power plants, some of the nitrogen in the atmosphere also combines with oxygen to produce various kinds of nitrogen oxides. Nitrogen oxides and sulfur dioxide combine with moisture in the atmosphere to produce nitric and sulfuric acids, the cause of acid rain in eastern North America. Rain is ordinarily somewhat acid, but the addition of sulfur and nitrogen oxides makes it strongly acid. This precipitation sets the stage for a complex and far-reaching chain of events that can kill certain kinds of plants and aquatic life of all sorts.

Midwestern power plants and automobiles are the chief sources of acid emissions, which generally become a major problem only when they concentrate over rocks with naturally high acid content, a situation which develops in the northeastern United States and southeastern Canada. Acid rain is not typically a problem in Missouri, both because we are at the western edge of the chief midwestern sources, and because we have deep layers of carbonate rocks to neutralize the rain's worst effects. Nonetheless, delicate organisms, such as lichens, are often eliminated locally by high sulfur dioxide concentrations.

Unfortunately, most of our engines are not 100 percent efficient and some of the fuel passes through without being completely burned. This unburnt fuel contributes to the load of organic compounds or hydrocarbons in the air. Partially burnt fuel is also discharged as carbon monoxide, a potentially lethal gas. Lubricating oil that slips past worn valves or piston rings is vaporized or only partially burned. And whenever a fuel tank is filled, the influx of liquid causes an equivalent outrush of vapors. These oil and fuel vapors also add to the hydrocarbons in the atmosphere.

Jon Hawker

A stable air mass or thermal inversion can trap pollutants in an urban environment, as happened in St. Louis in September 1991.

When sunlight strikes a mixture of hydrocarbons and nitrogen oxides, along with oxygen and water vapor (always abundant in Missouri air), a number of reactions can occur, resulting in the formation of ozone, hydrogen peroxide, and a substance called peroxyacetyl nitrate (PAN), as well as other noxious products, including formaldehyde. Formaldehyde is a toxic, cancer-inducing material used to embalm bodies for burial or scientific study. Ozone, hydrogen peroxide, and peroxyacetyl nitrate are powerful oxidants and rapidly deteriorate rubber, nylon, and other materials. These oxidants, along with sulfur dioxide, kill vegetation outright and accentuate a number of human ailments. Asthma attacks, eye irritation, athletic or work impairment due to breathing difficulties, and acute stress in people with chronic respiratory diseases increase when photochemical smog is present. Other pollutants play a role as well. Carbon monoxide impairs time and visual discrimination, causes headaches, and increases heart stress in people with cardiac ailments. During air pollution alerts, when concentrations of these chemicals reach high levels, the death rate in a city climbs measurably. But if the atmosphere is constantly circulating, why are there air pollution alerts, periods when pollutants are especially bad?

It is not uncommon in the Midwest, however, for exceptionally stable air masses to move into the Mississippi Valley and take up residence for days, or even weeks. These are especially common during the hot summer months. Another phenomenon, called a thermal inversion, may happen at any time. Under normal circumstances, as we rise in elevation or altitude we usually notice a decrease in temperature, what is called adiabatic cooling; the higher we go, the colder it gets. Under the right conditions, however, an isolated layer of warm air may develop anywhere from 500 to 5500 feet above the ground that can trap cooler air near the surface.

The effects of stable air masses and thermal inversions are roughly the same. Anything and everything dumped into the atmosphere remains until a front moves through and flushes the whole system clean again. Pollutants accumulate, solar energy is absorbed, and the chain of photochemical reactions is set in motion. The haze increases and breathing may become more difficult. After a few stagnant days, it is likely that an air pollution alert will result.

A similarly stable situation occurs on a daily basis because of the enormous amount of heat trapped by concrete and bricks during the day and reradiated at night, warming urban air noticeably. This causes a change in air circulation called the heat island effect; hence evenings and mornings are usually cooler in the suburbs. Like stable air masses and inversions, a heat island can also trap polluted air, leading to the dust dome or haze hood that envelops the entire metropolitan area and is so obvious at a distance.

In the long haul, the Earth has a fairly stable temperature, maintained for eons by a balance between combustion and respiration, on the one hand, and photosynthesis on the other. Plant growth and subsequent events binds carbon dioxide - scientists say "fixes carbon" - into more permanent forms, such as wood or fossil fuels. These keep atmospheric levels relatively low. The result is a balance between the input of sunlight and the Earth's output of heat. In general terms, what we gain during each day's rise in temperature, we lose the following night.

Best guess predictions estimate that at current rates, global warming will lead to a rise of three to nine degrees Fahrenheit within the next century. While that may not sound like an alarming figure, an Ice Age, created when the globe absorbs much less light because of its position relative to the sun, only lowers the Earth's temperature by about nine degrees Fahrenheit. A few degrees of warming will melt polar and mountain snow and ice and flood low-lying areas, including much of the world's agricultural land and many major cities. Ocean and atmospheric currents would change, creating deserts in place of farmland. The planet Venus, much closer to the sun, and with an atmosphere of nearly pure carbon dioxide and a surface temperature of roughly 900 degrees Fahrenheit, provides an extreme model of the greenhouse effect. It would seem prudent to lower our production of greenhouse gases, especially CFC's, which have other deleterious and more immediate effects.

As sunlight enters the Earth's atmosphere, its high-energy ultraviolet component - the portion that causes sunburns and skin cancers - splits oxygen molecules, a union of two individual oxygen atoms, into what are called **oxygen radicals**. These free oxygen atoms often recombine immediately to recreate oxygen molecules, but they are also free to recombine in other ways, including threesomes called **ozone**. The thin zone of ozone creation and the ozone layer produced lie roughly 32 miles overhead. Thin though the zone may be, it absorbs 99 percent of the ultraviolet light entering the planet's atmosphere, protecting all forms of life from deadly radiation. This high-altitude ozone should not be confused with the ozone polluting our air at the Earth's surface. Ozone is toxic and destructive when it contacts living things or materials. At 30 miles, it contacts very little. Unfortunately, the very things that increase ozone at ground level decrease it 30 miles up.

Chlorofluorocarbons released from leaking and discarded cooling systems, or escaping while air conditioners or refrigerators are being serviced, from aerosol cans, and from plastic foam and other sources gradually drift up into the atmosphere. Once in the ozone layer, the CFC's gobble up ozone molecules like chemical Pacmen; one CFC molecule is capable of destroying 100,000 ozone molecules. Evidence that this is taking place comes from studies of a large hole in the ozone layer over the South Pole that has increased in size each year for the past 20 years. The long-term effects of ozone depletion would be disastrous.

Studies have concluded that a five percent decrease in ozone concentrations would raise the number of skin cancers in the United States by a million cases each year, suppress our immune systems, increase the occurrence of cataracts and severe sunburn, heighten the production of photochemical smog, and raise global temperatures. Fair-skinned Australians, who live under a portion of the growing ozone hole, and who are also renowned for their addiction to bare-skinned activities, suffer the highest incidence rate of skin cancer in the world. Evidence such as this prompted 80 nations to begin working to reduce and eventually eliminate CFC emissions. Unfortunately, similar international determination and cooperation have not surfaced where other greenhouse gases are concerned, most notably carbon dioxide.

The most obvious method of reducing emissions is one lost on most people; simply reduce consumption. Few people make the connection between leaving a light on in the next room and dying forests in the northern Appalachians, or the link between driving to work by oneself and the orange haze blanketing the city. A conscientious effort to reduce all forms of energy consumption could reduce harmful emissions by half. Unfortunately, along with with their many other liberties, Americans are also reluctant to curb their freedoms to consume and to go where they want, when they want. Electricity and the automobile, more firmly parts of American culture than any others, have given us those freedoms.

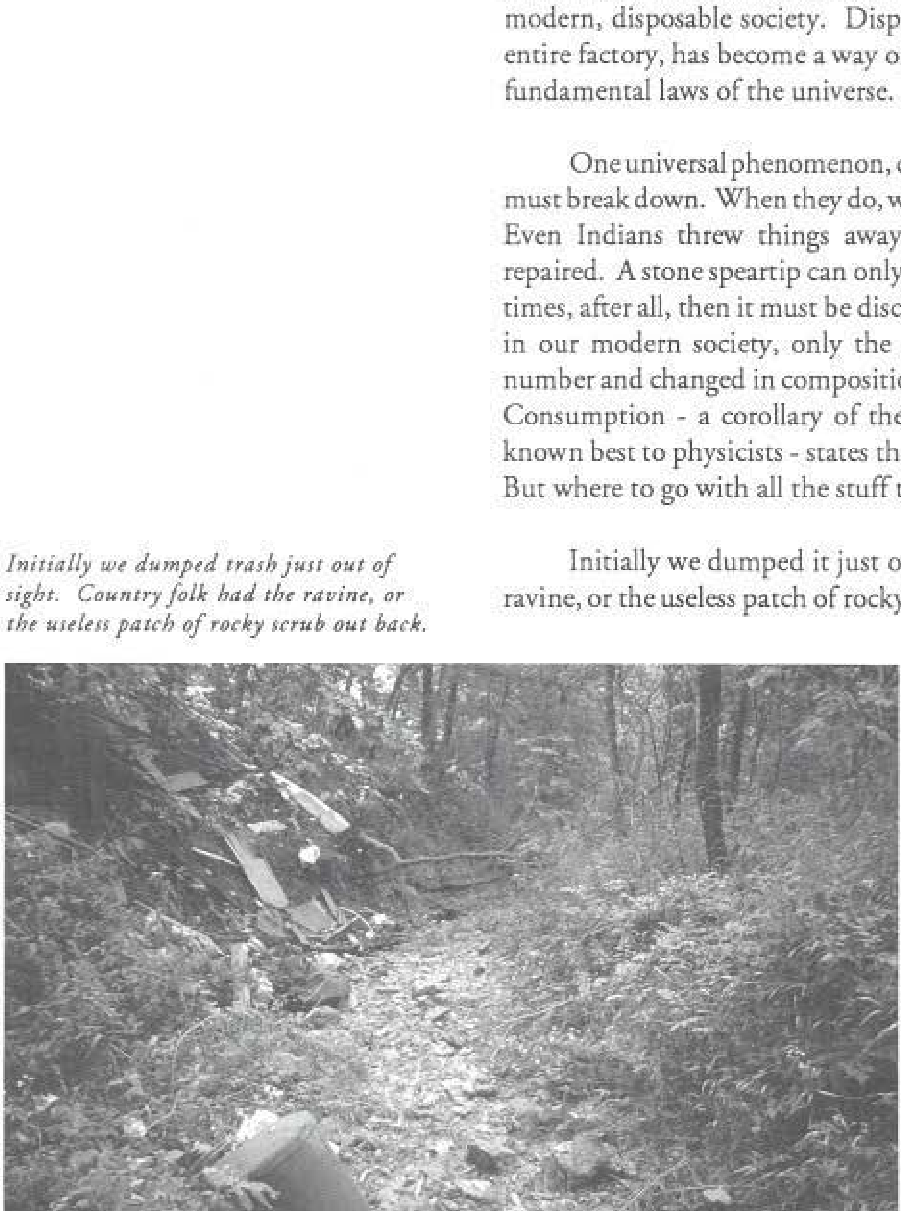
The Electric Age - The Age Of Trash

Technological progress in the early 20th century changed the Missouri landscape in an almost uncountable number of ways. Electrification changed the basic ways in which we lead our lives, providing light for activities after dark, heat for comfort, and power for processing resources into metals, machines, and conveniences never available before. Mining, refining, manufacturing, architecture, and construction were revolutionized by electricity, ultimately lowering the cost of goods and services, increasing our standard of living, and changing the face of our country. Aluminum was converted from an expensive and rare oddity to a metal for the masses. Electrical household luxuries and conveniences freed us from time-consuming chores, gave us weekends to play, and soon became necessities. Time and life, education, recreation, commerce, and production now hang in the balance whenever the power goes out.

The rocketing price of land forced cities upward as well as outward, and the new technology allowed the upward and outward growth, filling the state's air space with dwellings, businesses, monuments, and recreational complexes, altering the urban horizon forever. The new breed of cliff-dwellings became so massive they created their own urban climate. Technology and affluence permitted buildings to be abandoned, torn down, or replaced, rather than repaired or restored. Urban blight, the desertion of city centers, and the expansion of the suburbs became a national phenomenon. The once-attractive urban environment became an ugly eyesore to be avoided, relegated to those who could afford no better.

Electrical technology also led to the construction of high dams, coal-fired and nuclear power plants; air pollution and radioactive wastes; thousands of miles of countryside permanently bound up under high tension power lines; an urban landscape forested by utility poles and populated by generations who have never seen the stars. Without electrification we would never have had gravel bars and roadsides littered with pop-tops and empties, yards and gullies choked with discarded appliances, or video games. Finally, technological progress, based on the ready availability of energy, spawned our modern, disposable society. Disposal, from a candy wrapper to an entire factory, has become a way of life and a critical issue because of fundamental laws of the universe.

One universal phenomenon, called entropy, demands that things must break down. When they do, we can either repair or replace them. Even Indians threw things away when they could no longer be repaired. A stone speartip can only be reflaked to a fine edge so many times, after all, then it must be discarded. The same principle applies in our modern society, only the objects discarded have grown in number and changed in composition. The First Law of Conspicuous Consumption - a corollary of the Law of Conservation of Matter known best to physicists - states that everything must go somewhere. But where to go with all the stuff that breaks down?



Initially we dumped trash just out of sight. Country folk had the ravine, or the useless patch of rocky scrub out back.

Nick Decker

Initially we dumped it just out of sight. Country folk had the ravine, or the useless patch of rocky scrub out back. City folk had the bonfires or ash pits in which to burn inflammables, and the vacant lot next door or the undeveloped land at the end of the street for nonflammable waste. Because of the volume of trash, the threat of disease, and the sheer ugliness, towns and cities were eventually forced to create centrally-located dumps, again just out of sight. As the city grew, a transportation system was needed as the distance to "just out of sight" also grew. Eventually, the town dump became a "sanitary landfill," where deliveries were buried under a veneer of soil each day to prevent spread by wind, disease, or fire. Not faced with the same volume of trash, some country folk continued to dump out back (or alongside, or in front). Often viewed as an inherent Ozark trait, trashing the landscape is a worldwide phenomenon wherever land is less valuable than debris, and no cheap and convenient system of disposal exists.

The astronomical rate at which Americans use and discard resources has spawned a growth industry of its own, one that threatens to bury us all. While the NIMBY (Not In My Back Yard!) attitude understandably squelches the development of new disposal sites, most of our present landfills will be full within a decade. Before it is finally closed, the landfill in west St. Louis County, for instance, will likely become the highest point in the region. On the evening news Missourians have laughed at trash-filled ships drifting the Seven Seas, like the Lost Dutchman, searching for a final resting place. Yet Missouri looks enviously at its own neighbors as potential dump sites, having exported waste for years, while attempting to shut its own doors to imported refuse from as far away as the state of New Jersey.

While landfills are inevitable and will never be eliminated, two seemingly simple approaches stand out as realistic solutions. Since every Missourian currently produces 3.7 pounds of trash a day, not counting industrial or agricultural waste, simply reducing the amount of materials that are destined to become waste would obviously reduce the scope of the problem. Products and the packaging systems they come in must both be designed with final disposal in mind. For example, double, triple, and quadruple packaging systems (a wrapped, bottled product in a box, sealed in a plastic wrapper, handed to us in a bag) are beyone what is absolutely necessary. Augmented by enhanced and efficient recycling systems, more than 70 percent of current trash could be simply eliminated.

Changing landfill laws, such as excluding yard wastes, lead acid batteries, tires, and appliances, will hopefully force changes in consumption patterns that are long overdue. These changes will extend the lives of current landfills, slow the depletion of natural resources that might be put to better use, lower the amount of energy wasted on the production of new goods and the disposal of the old and discarded, and reduce infiltration of toxic materials into Missouri's groundwater and streams.

The Automobile Age

Perhaps no single invention has so altered our landscape as has the internal combustion engine. Besides the obvious - millions of acres of asphalt and concrete that criss-cross the continent at every latitude and longitude, for instance, the urban and suburban sprawl - a century of accommodating the auto has resulted in massive changes we take for granted or barely notice.

Second only to electrification, the advent of the internal combustion engine and its godchild, the automobile, became a true measure of American prosperity in the 20th century. Gasoline and diesel engines lead to independence for the masses, increased and sped the availability of goods and services, and, once again, completely altered lifestyles and the landscape.

By making transportation a personal issue, distances traveled to work or play became a matter of choice. Cities sprawled outward as affluence increased and the affluent choose to abandon the crowded, polluted urban environment. Road-building became a national pastime, an on-going summer adventure without end. Agricultural land was inexorably paved over in favor of roadways and berthing places. As land prices rose, housing mushroomed farther and farther from the workplace. All manner of services necessarily followed, from gas stations, shopping centers, and dry cleaners, to sewer, utility, and water lines. Post-war prosperity gave more Americans access to the automobile in the 1950's than ever before. "Drive-in" was already a well-worn phrase by the 60's. With their cars, Americans could get out and "see the USA," and did.

The automobile industry became a barometer of the nation's economic health. Besides giving jobs and financial security to hundreds of thousands, the automobile touched nearly everyone's life. The vast majority of people own a car and virtually no one doesn't drive. We give cars pet names and use them to measure our lives. We may not remember what year we did such-and-such, but we always remember what car we owned when we did it. Hundreds of thousands of people have been conceived in autos, while hundreds of thousands more have died on America's roadways. When finally moribund or dead, the family car may be recycled as scrap or not, depending on the economic times and the price of steel. Often hardly worth the trouble of gathering and hauling, thousands of abandoned hulks litter the Missouri landscape.

Had the internal combustion engine been used solely for the production of automobiles, the impact would have been phenomenal. But since these engines also allowed the development of airplanes, chain saws, bulldozers, and bass boats, their development has gone far beyond the merely phenomenal. Engines, whether in cars, trucks, buses, trains, or planes, deliver us and our goods quickly anywhere in the world. Our far-flung transportation system has eliminated places where one can escape the sound of an engine or the pollution it leaves in its wake.

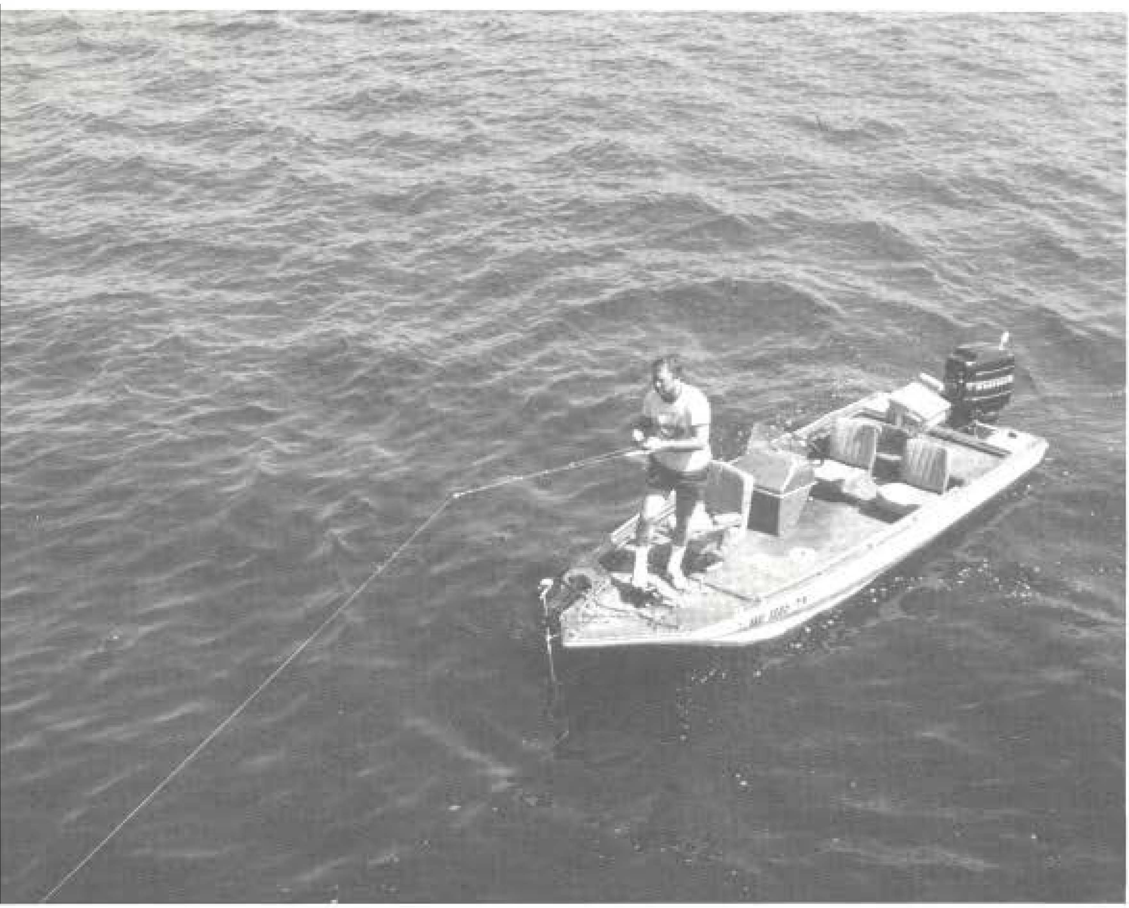
The airplane made international travel commonplace, bringing changes in diplomacy, warfare, communication, recreation, medical aid, and the spread of disease. With airplanes came airports that paved huge expanses of suburban land for runways, parking lots, access roads, and light rail systems. An airplane roaring overhead or sparkling in the night sky are images in our landscape unknown to those living in any other century.

With a chain saw, whole forests can now be cleared, bringing a single person the same power once reserved for a forest fire or volcano. The internal combustion engine powers the bulldozer that levels hills, fills valleys, and alters drainage patterns in ways that have not been seen since the Kansan ice sheet crept over the state nearly a million years ago. Gasoline and diesel engines motivated the farm equipment that made America the breadbasket of the world, and then helped turn the American family farm into another corporate venture. Every year billions of dollars pour into

Gasoline and diesel engines led to independence for the masses, increased and sped the availability of goods and services, and completely altered lifestyles and the landscape.

Nick Decker

the mowers that graze America's deforested lands in pursuit of the perfect lawn and an immaculate roadside.



Nick Decker

With the rise of the bass boat, flood control and electrical generation have become almost secondary provisions of reservoir construction, compared to the economic impact of lakeside recreation. Recreation in its many forms is now as dependent on the internal combustion engine as are work and production. If not driving their cars or motorcycles for pleasure, or being driven, Missourians scoot across lakes or up and down streams in power boats or on self-propelled skis, sail overhead in their own or borrowed planes, or careen around confined spaces in dune buggies, go-carts, and bumper boats. Even if not participants, Missourians travel by the tens of thousands to enormous stadiums to watch their favorite teams do battle.

With the rise of the bass boat, flood control and electrical generation have become almost secondary provisions of reservoir construction, compared to the economic impact of lakeside recreation.

The availability of the internal combustion engine also spurred the growth of the petroleum industry, as well as proportionate growth in both the rubber and steel industries. Their growth was followed by the development of the petrochemicals and plastics industries. The Father of Waters is now the source of water for hundreds of refineries and manufacturing plants that grew out of this development, line its banks, and pollute its waters. These industries have changed our lives and our landscape in countless ways. Without plastics we would cut our feet on broken glass in the shower, drive heavier, less efficient autos, and ingest lead from old-fashioned toothpaste tubes. But without them we could also float a wooded stream or drive an interstate highway unadorned by trash bags, disposable diapers, and styrofoam cups.

Every phase of American life has been touched by the advances that followed from the development of electricity and the internal combustion engine. Obviously, these touches have been schizoid, with both positive and negative effects. Both a proud and a sad fact is that no other nation can boast of our per capita consumption of energy and resources.

The combustion of fossil fuels and destruction of vegetative cover that have accompanied the development of our engine-centered culture may be causing atmospheric and climatic changes that would normally take millions of years. It is possible that carbon dioxide levels are higher now than at any time since the Carboniferous Period or the Age of Dinosaurs. Will these changes bring even more benefits to generations yet to come, or will they cause catastrophic climatic changes? Only time will tell.

Throughout geological time, since the formation of the Earth, its oceans, atmosphere, and continents, the drifting of those continents into their modern positions, and their scouring by glacial ice, no single event has had greater impact on the Missouri landscape than the appearance of the human animal. Humans have shown that they have the power to create and destroy on a truly monumental scale. The past three centuries have begun to teach us - only just begun to teach us - of the magnitude of those powers. The next century will tell if we have learned to manage and direct that power constructively towards our landscape .

The Centuries Ahead

The fact that natural plant and animal systems are alive and well in Missouri after centuries of human-caused physical, chemical, and biological change is testimony to the resiliency of those natural systems. What kind of landscape will future residents of Missouri inherit?

Into The Future

This book has described those processes of the past five billion years which have shaped the modern Missouri landscape. We have provided snapshot-like images of the major stages in the long development of the earth, its air, and waters. Now our attention naturally shifts from the past and present to the future. What changes will the next five billion years bring to our landscape? The next century? The next year? As everyone knows, predicting the future is always an iffy business and there are some things at which we can only guess, others at which we might take an educated stab.

Will the Ozarks experience another uplift and erosional cycle similar to the three that have occurred in the past 1.4 billion years? Will great volcanoes spout again from its currently docile surface or is this a landscape in erosional old age, destined to be washed away to the level of the sea? Will the fractured rock beneath the Mississippi Embayment sink even further than it did during the reign of the dinosaurs? Is that what the constant commotion in the New Madrid Seismic Zone is all about? These are certainly interesting questions to ponder, and probably important to Missouri residents a hundred or a thousand generations from now, but hardly the stuff about which we can make precise predictions, certainly not with the precision necessary to formulate public policy.

Other long-term scenarios are more predictable and are of undisputed importance. Yet even these events are so distant they create little concern and, in any event, defy planning. We know from studies of celestial bodies throughout the universe, for instance, that stars like the sun evenually cool and die as their internal nuclear reactions slowly fizzle. What do we do when that happens to our own sun? We know too that the continents are constantly on the move. Will flowing magma beneath the earth's crust drag North America into new latitudes, changing climates as it has in the past? We also know that cycles of changing earth position relative to the sun have created numerous glacial periods. Will continued cycling in the solar system bring another Ice Age to the globe and yet another ice sheet to the Midwest?

These all seem like good scientific bets, but they're not likely to stir much alarm out on the street. Missourians going about their daily lives cannot be expected to alter their activities in the face of such long-term, even if inevitable changes. Nevertheless, there are going to be some predictable changes in the Missouri landscape that should force a shift in our activities, changes that warrant public policy decisions. The most significant of these is continued technological growth in the hands of an unchecked human population.

All living things in the natural world are constrained by the limits of food, water, air, space, and competition with other species. In general, the earths's resources are fully exploited by life. There is hardly a patch of Missouri, for instance, that does not support some kind of creature, however simple. To grow in numbers or to fill more space, a species of plant or animal must necessarily displace others. Its food, water, space, and air must be wrenched from another. Anyone observing a major natural system for a time, however, recognizes that no species seems to get the upper hand for long. There is something at work we call the "balance of Nature."

A species can only compete for food, water, and space with whatever tools it has inherited from previous generations. Likewise, its neighbors in forest and field can only do the same. Seldom does one kind of plant or animal get an edge on those around it. An advantage gained by one species in a system is usually met by increased leverage among the others. In this way the balance tends to be maintained. If one species does manage to acheive superiority by inheriting a turly beneficial trait, it expands at the expense of its neighbors. During the late Paleozoic, for example, trilobites replaced animals that had filled the seas for millions of years. Later, dinosaurs prospered while more primitive amphibians and reptiles that had originally conquered the land in the name of vertebrates declined. Once the great Mesozoic reptiles died out, mammals and birds thrived in their absence. Now, with inherited hands and brains, we humans have gained the ultimate edge over all other living things.

Thousands of years ago, while simply helping us humans extract a living, the natural superiority of our hands and brains helped push North America's Pleistocene megafauna into extinction. So successful at extracting a living were these ancient hands and brains, they left their mark even into the present. Fire, farming, and mound-building scarred the natural Missouri landscape in ways that remain visible a thousand years after the hands and brains themselves have vanished.

In the 19th Century, new hands and brains cleared Missouri's forests, plowed her prairies, and decimated her wildlife. Using materials and tools not available earlier, the thin mantle of life that had covered Missouri for millenia was devastated in a single century. The "balance of nature" was swung forever into the grip of a single species, the only species in possession of what we call **technology**.

Armed with 20th Century technology, the hands and brains of this single exceptional species then went after the very earth itself, leveling hills, filling valleys, straightening and damming great rivers,

Giant earthmoving machines, sometimes assisted by explosives, can make landscape changes in days that "Mother Nature" would need millions of years to accomplish.

CATERPILLAR

Jerry D. Vineyard

covering the land with enormous structures, producing huge amounts of wastes, even altering the climate. Seemingly unrestrained by natural constraints that limit other kinds of plants and animals - food, water, air, space, and competition - humans have expanded at a rate unseen in the history of the planet.

Whether competitor, predator, pest, weed, or disease, technology has seldom failed to suppress threats to human supremacy. We are able to squelch those around us with an ease unknown to any other species in the four-billion-year history of life on earth. Perhaps more importantly, we are able to control the very nature of the system in which we live. We do this by replacing naturally-balanced systems with human-generated systems that are unnatural and unbalanced. A cornfield is more than a triumph over predators, pests, weeds, and diseases; it is a triumph over all the plants and animals that occupied the land before the cornfield was created. But it is not ultimately a triumph over the laws that govern such systems. Our systems are only maintained in their unnatural, unbalanced states with great effort, with enormous amounts of energy, and at great expense.

We might argue that the changes we make are simply a product of our natural superiority over other species, that we were destined to bend planetary systems to our will. Hands and brains have certainly made such an outcome possible. However, this approach denies our special human ability to examine, appreciate, and control what we do to our surroundings. The locust in a plague is totally unaware of the combined impact of its fellow millions, that its swarm is doomed as all available food is consumed. With truly mindless disregard for anything but their own bellies, individual locusts clamber for their share.

Humans are undoubtedly capable of doing the locust thing, and they are also capable of going locusts one better through the use of technology. The swarm of locusts quickly dies off and the damaged system recovers sufficiently to allow the locusts to swarm again. Equipped with technology, the human swarm can continue to damage the system and prevent repair. Even allowing for recovery, are we prepared for the human swarm to die off like locusts?

Fortunately, the birth of the 20th century also brought to many people a heightened awareness of the value of the many species and natural systems around them. They recognized a truth often masked by air-conditioning, sandwich bags, and milk jugs; humans are totally dependent upon natural systems and natural cycles. In a most unlocust-like fashion, hands and brains were turned to the task of

Nick Decker

Ironically, in the future this farmland may be covered with houses holding people who would prefer living away from the crowds -- maybe on a farm, but there won't be any space left.

preserving and restoring species and portions of natural systems lost in the preceding century or destined to be lost soon. Looking around at Missouri's numerous preserved and conserved lands, and her restored species, we might say they have succeeded very well. Wildlife seems to be thriving, wild lands are readily available to many, and air and water seem in better shape than in the past.

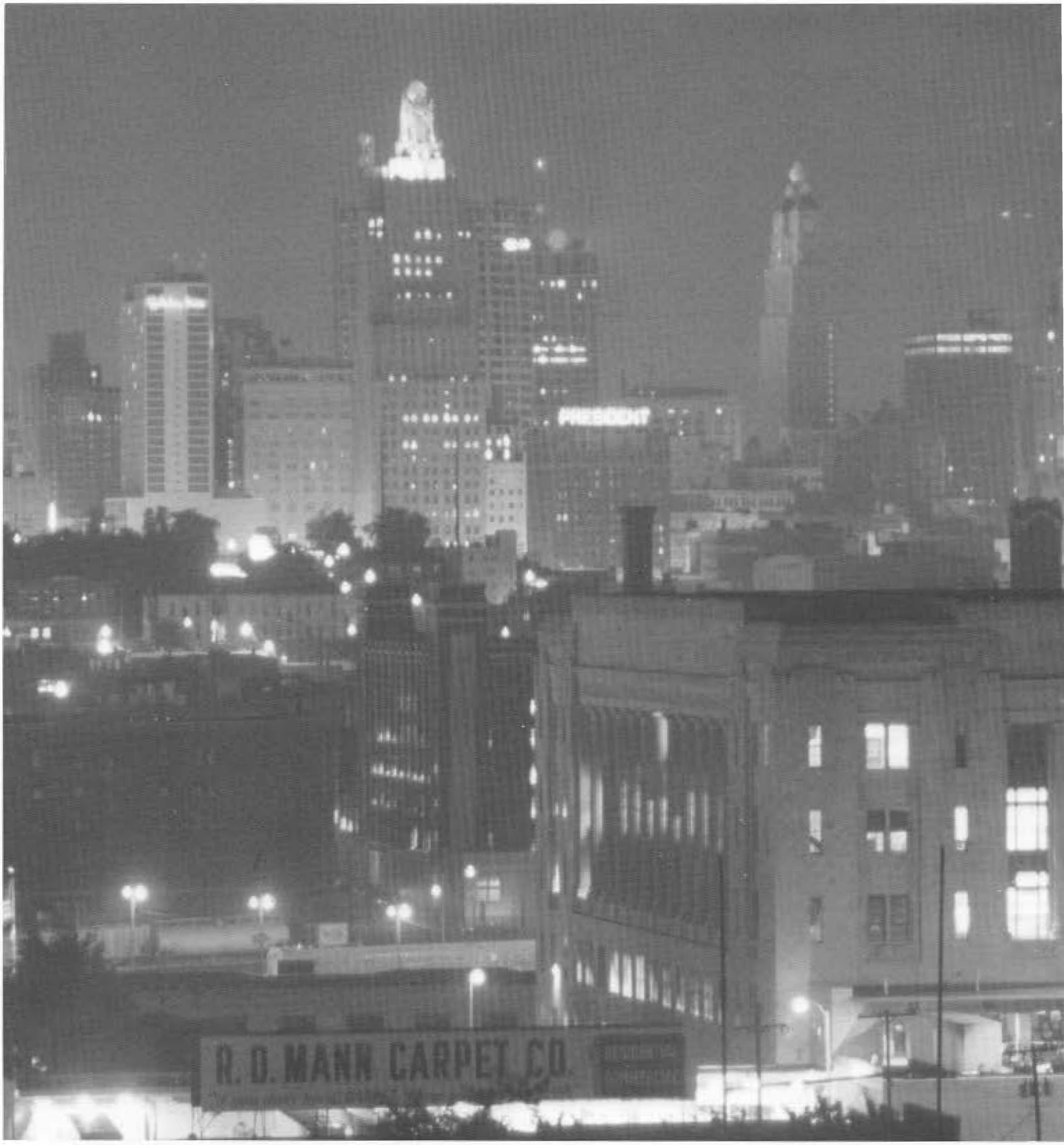
There is another disquieting truth at work, however. Common sense tells us that the 44,598,976 acres granted Missouri at statehood can only absorb so much change before all vestiges of its original landscape are lost forever. Logic dictates that the land can hold only so many people and absorb so much pollution before its ability to support life is also lost. We know that by 1980, 3,000,000 of Missouri's originally prairied and forested acres had been paved or built upon, 15,000,000 had been plowed, 13,000,000 grazed, 600,000 permanently flooded, and 150,000 mined. As we have seen, the original stands of timber on most of the remaining land had been completely logged off much earlier. Only a few thousand acres of presettlement Missouri remain reasonably intact. Like islands, these can be easily overcome by the rising tide of development around them.

A first-time visitor to the Grand Canyon is invariably awed by the sight, even though the other side of the canyon is seldom clearly visible these days because of pollution that has driftd many miles from power generation plants. Hikers might thrill to the wilderness experience except for the constant helicopter and airplane traffic overhead. Thus it is with islands of wild in a sea of development. Of course, we can argue that Las Vegas has a right to bright lights and non-hikers have the same right to drop down into the canyon for a closer look as do hikers.

Missourians have brought a sense of what is right and the force of law to bear on many of the problems rising from uncontrolled development. Missourians clearly do not want the entire state dedicated to the human population alone or to the production of human goods. We have salvaged large tracts of forest and patches of prairie; we have preserved irreplaceable stretches of streams and set aside examples of unique natural systems; and we have restored many species to healthy numbers. We have begun cleaning the pollution from our air, soil, and water. We are beginning to understand the long-term effects of rampant soil erosion. We are beginning to see the value of recycling and energy conservation. Yet we remain some distance from solving a number of critical environmental problems. The preceding sections outlined some of the issues facing us and offered some not-so-simple suggestions, such as curbing consumption.

Yet even if Missourians curb their consumption of resources and their production of wastes by carefully monitoring the growth, uses, effects, and directions of technology, a rising human population will not allow much of the Missouri landscape to survive. Armed only with limited technology, the flood of humans in underdeveloped nations strips the lands of its natural resources. The combination of population growth and technological expansion fuel Missouri's economy and drive its legislative enactments. Can Missourians pass laws that will apply limits to their own prosperity and spare their landscape, a landscape on which they depend? This is not a question that science can answer.

Technology enables the human species to raise artifical landscapes used for living and working space, for governance, communication, and even for aesthetics -- something alien to any other species that ever lived on earth.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MISSOURI DEPARTMENT OF NATURAL RESOURCES' DIVISION OF GEOLOGY AND LAND SURVEY

On February 24, 1853, the Missouri Legislature created the first state agency commissioned to study the natural resources of Missouri -- the Geological Survey of Missouri. George Clinton Swallow was appointed state geologist and became the first director of the agency.

At the beginning of the Civil War, the survey was discontinued. It was reinstated in 1870 as the Missouri Bureau of Geology and Mines but became inactive in 1878 after the resignation of state geologist, Charles Williams. The survey was reestablished May 18, 1889 and, as the third geological survey of Missouri, became the direct predecessor of today's Division of Geology and Land Survey.

In 1933, the survey was renamed the Missouri Geological Survey and Water Resources. With state reorganization in 1974, the Geological Survey, along with the Land Survey Authority, created in 1970, were placed together in the Department of Natural Resources to form the department's Division of Geology and Land Survey. Later, in 1981, legislation created the Dam and Reservoir Safety Program and placed it in the same division. The Water Resources Program was added in 1987.

The survey has had its headquarters in Rolla since 1901, and has been located in the Buehler Building on Fairgrounds Road since 1963. In 1984 an adjacent building on Gale Drive was modified for the Land Survey Program; and in 1989 a building was purchased on Research Drive in Dietzmann Industrial Park to house the McCracken Core Library.

On October 13, 1989 the Division of Geology and Land Survey celebrated 100 years of continuous service to the people of Missouri, and also dedicated the McCracken Core Library.

The Division of Geology and Land Survey has an experienced staff of geologists, land surveyors, engineers, planners, soil scientists, hydrologists, technicians, and support personnel. The division's five programs include Administration, Geological Survey, Water Resources, Land Survey, and Dam and Reservoir Safety.

Visitors are welcome at Division headquarters on Fairgrounds Road in Rolla, and guided tours may be arranged. For more information call (314) 368-2100 or write P.O. Box 250, Rolla, MO 65401.

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